DRAFT

Development and Screening of Remedial Alternatives Technical Memorandum

HOMESTAKE MINING COMPANY SUPERFUND SITE

OPERABLE UNIT 1: GROUNDWATER RESTORATION

AND

OPERABLE UNIT 2: MILL DECOMMISSIONING, SURFACE SOILS, AND TAILINGS RECLAMATION

Near Grants, New Mexico

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ACRONYMS AND ABBREVIATIONS

ACM	asbestos containing materials
ACOE	U.S. Army Corps of Engineers
ALARA	`as low as is reasonably achievable
ARARs	Applicable or Relevant and Appropriate Requirements
BERA	Baseline Ecological Risk Assessment
bgs	below ground surface
CAA	Clean Air Act
CWA	Clean Water Act
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CFR	Code of Federal Regulations
cm	centimeters
COC(s)	contaminants(s) of concern
DOE	Department of Energy
DP	Discharge Permit
EC	electrocoagulation
EP	Evaporation Pond
EPA	United States Environmental Protection Agency
EPC	exposure point concentration
ERG	Environmental Restoration Group, Inc.
ESV(s)	ecological screening value(s)
FS	Feasibility Study
ft	feet
gpm	gallons per minute
HMC	Homestake Mining Company
HQ	hazard quotient
ICs	Institutional Controls
LANL	Los Alamos National Laboratory
LTP	Large Tailings Pile
LTA(s)	Land Treatment Area(s)
LOAEL	Lowest Observed Adverse Effect Levels
mg/kg	milligrams per kilogram

mg/L	milligrams per liter
mrem/yr	millirems per year
NESHAPs	National Emission Standards for Hazardous Air Pollutants
NM	New Mexico
NMAC	New Mexico Administrative Code
NMED	New Mexico Environment Department
NMSA	New Mexico Statutes Annotated
NOAEL	No Observed Adverse Effect Levels
NRC	Nuclear Regulatory Commission
OU	Operable Unit
pCi/g	picocuries per gram
pCi/L	picocuries per liter
pCi/m^2s	picocuries per meters squared-second
Ra-226	Radium-226
Ra-228	Radium-228
RAOs	Remedial Action Objectives
RESLs	radioecological screening levels
RI	Remedial Investigation
Rn-222	Radon 222
RO	reverse osmosis
ROI	radius of influence
ROPC(s)	radionuclide(s) of potential concern
Site	Homestake Mining Company Superfund Site, Cibola County, New Mexico
SMDP	Scientific/Management Decision Point
STP	Small Tailings Pile
TBC	to be considered
TDS	total dissolved solids
TEDE	total effective dose equivalent
Th-228	Thorium 228
Th-230	Thorium-230
TPP	tripolyphosphate
U	uranium
U-234	Uranium 234

U-235	Uranium 235
U-238	Uranium 238
UCL95(s)	upper 95th percentile confidence limit(s)
UMTRCA	Uranium Mill Tailings Radiation Control Act of 1978
USC	United States Code
V	vanadium
WL	Working Level
WTP	water treatment plant

SECTION 1 INTRODUCTION

This Development and Screening of Remedial Alternatives Memorandum identifies and provides an initial screening of remedial technologies potentially applicable for Homestake Mining Company Superfund Site, Cibola County, New Mexico (Site). Initial screening was completed for Groundwater Restoration (Operable Unit 1 (OU1)) and for Mill Decommissioning, Surface Soils, and Tailings Reclamation (Operable Unit 2 (OU2)).

[This document was prepared by the Homestake Mining Company of California (HMC) pursuant to the Administrative Settlement Agreement and Order on Consent between Environmental Protection Agency (EPA) and HMC (Settlement Agreement).]

1.1 PURPOSE & ORGANIZATION

This memorandum was prepared to identify potentially applicable remedial alternatives that could be used to address site-related contaminants of concern (COC), principally metals that have been detected in ground water and radon emissions. The process for screening of remedial alternatives follows the EPA *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (EPA 1988). The identification and screening of remedial alternatives is a step in the process of generating the Feasibility Study (FS) for the Site. The next step in generating the FS will be the detailed analysis of remedial alternatives, to be documented in the FS Report.

The remainder of this memorandum is organized in the following sections:

- Section 1.2 – Remedial Investigation (RI) Summary: This section summarizes the RI, including the ecological and hydrogeological setting, remediation history, the nature/extent of the contaminants of concern (COCs), and the human health and ecological risk assessments.

- Section 1.3 – Applicable or Relevant and Appropriate Requirements (ARARs): This section summarizes the ARARs applicable to the planned remedial action.

- Section 1.4 – Remedial Action Objectives (RAOs): This section identifies the RAOs based on the potential risks.

- Section 2 – - Areas and Volumes of Contaminated Media: This section describes the areas and volumes of contamination exceeding RAOs and requiring evaluation of remedies.

- Section 3 – Treatability Studies: This section identifies and summarizes treatability and pilot studies of candidate technologies that have been conducted at the site which are relative to the evaluating technologies that may be applicable to this Site.

- Section 4 – General Response Actions: This section describes general response actions for each medium of interest, defining containment, treatment, excavation, pumping, waste relocation or other actions, singly or in combination, to satisfy the RAOs.
- Section 5 – Identification and Screening of Remedial Technologies and Process Options: Remedial technologies and process options are identified and screened on the basis of implementability, effectiveness, and relative cost.
- Section 6 – Assembly and Refinement of Remedial Alternatives: This section assembles screened remedial technologies and process options into remedial alternatives that address the RAOs that are defined in Section 1.4.

1.2 RI Summary

The Site is the location of a uranium mill that operated from 1958 until 1990. Tailings from milling operations were deposited, primarily in the form of slurry, in two tailings piles, referred to as the Large Tailings Pile (LTP) and the Small Tailings Pond (STP). The LTP contains approximately 21 million tons of tailings, occupies approximately 215 acres, and is approximately 70 to 90 feet tall with side slopes of 5.0 horizontal and 1.0 vertical. The STP contains approximately 1.2 million tons of tailings, occupies approximately 40 acres, and is approximately 20 to 25 feet tall.

1.2.1 Summary of Environmental Setting

The climate of western New Mexico and the Site is generally a mild, arid to semi-arid, continental climate characterized by low precipitation, abundant sunshine, low relative humidity, and a large annual and diurnal (day and night) temperature range. Precipitation in the area averages approximately 10 inches per year. The majority of annual precipitation typically occurs during July, August, and September. The natural land surface at the Site is generally flat, with an average grade of 0.1 percent. Surface drainage across the Site is predominately directed to the southwest, although there are no established drainage courses or signs of active erosion. San Mateo Creek and Lobo Creek basins both drain onto the Homestake Facility (refer to Figure 1-1).

Current major land uses south and southwest of the Site consist of residential development, agriculture, and livestock raising. Five residential subdivisions near the Site include Felice Acres, Broadview Acres, Murray Acres, Pleasant Valley Estates, and Valle Verde (referred to collectively as “the subdivisions”). Some of the land within the subdivisions is used for agricultural and livestock purposes. There are large areas north, east, and west of the Site that are mostly unused except for livestock grazing (ACOE 2010).

1.2.2 Summary of Hydrogeologic Setting

The Site is underlain by unconsolidated alluvial materials resting on the incised surface of the Chinle Formation. The alluvial materials are a heterogeneous mixture of sand, silt, and gravel and comprise an aquifer with estimated hydraulic conductivities ranging from 10 to over 200 feet per day (HMC and Hydro-Engineering 2010). Depth to groundwater is 40 to 60 feet below ground surface at the Site. The thickness and extent of the saturated portion of the alluvial aquifer is shown on Figure 1-2 (HMC 2012).

Though the Chinle Formation is largely comprised of shale, there are three water-bearing units within the Chinle, including Upper and Middle Chinle sandstone aquifers, and the Lower Chinle aquifer consisting of a zone of enhanced water yield within the shale formation. The extent of the Upper, Middle, and Lower Chinle aquifers near the Site are presented on Figure 1-3, Figure 1-4, and Figure 1-5, respectively.

A regional aquifer, the San Andres Limestone and Glorietta Sandstone, exists at depth below the Site. The San Andres Limestone and the Glorietta Sandstone are hydraulically connected and considered to be a single aquifer in the Grants area, referred to as the San Andres-Glorietta aquifer. The extent of the San Andres-Glorietta aquifer is shown in Figure 1-6.

Bedrock units have tilted and faulted near the Site. As a result, all three Chinle aquifers subcrop with the overlying alluvial aquifer. Water exchange occurs between the alluvial aquifer and the Chinle aquifers. Areas within the Chinle aquifers close to the subcrop, where the water chemistry is comparable to the alluvial water, is referred to as “mixing zones”.

1.2.3 Summary of Site Remediation History

1.2.3.1 Groundwater

Site remediation of groundwater began in 1977. Since that time, the groundwater remediation system has evolved in response to improved understanding of Site condition, availability of better technology, and accumulation of experience at the Site. The current system includes multiple components that are frequently adjusted based on evaluation of monitoring data. The following provides a brief description of the components:

- Hydraulic Containment. Water is added into the alluvial, Upper Chinle, and Middle Chinle aquifers to create a hydraulic barrier to limit the movement of contaminated groundwater. The hydraulic barrier in the alluvial aquifer is created and maintained downgradient of the LTP. Injection into the Upper Chinle and Middle Chinle occurs east of where the aquifer subcrops the alluvial aquifer, and facilitates collection of impacted groundwater for treatment (HMC 2019a).

- Reverse Osmosis (RO) Treatment. The RO treatment has been used since 1999 to remove contaminant mass from on-site groundwater extracted upgradient of the hydraulic barrier. Plant influent is composed of groundwater from the alluvial aquifer, the Upper and Middle Chinle aquifers, and the collection ponds, which receives water from the RO plant. The RO plant treatment process includes a lime/caustic pre-treatment and clarification unit and microfiltration as pre-treatment to the three RO treatment units. Accounting for scheduled maintenance, the operational capacity of RO treatment is about 1,000 gallons per minute (gpm).

- Zeolite Treatment. Zeolite beds have been used since 2016 to remove the uranium from off-site collection water because uranium is the only site constituent that exceeds the site standards in this collected water. There are two zeolite treatment plants that have a combined operational capacity of 1,050 gpm (HMC 2019a).

- Evaporation. There are three lined evaporation ponds (EP-1, EP-2, and EP-3) in use at the Site (refer to Figure 1-1) to concentrate uranium and other contaminants. The evaporation system receives water from the extraction wells in the alluvial and Upper Chinle aquifers and brine from the RO plant. During 2018, approximately 200 gpm were evaporated from the ponds (HMC 2019a).

1.2.3.2 Mill Decommissioning

Demolition activities began on May 5, 1992, with removal of asbestos-containing materials (ACM) from various mill facilities prior to demolition. The ACM was disposed of in a disposal pit at the toe of the original slope of the LTP. Residual byproduct and scale materials were removed from milling process components before these components were demolished and buried. Byproduct materials consisting primarily of scale, sludge, and tailings in tank precipitators were removed by mechanized equipment and by hand tools and hauled to the large tailings impoundment for burial. Demolition of milling facilities was completed by March 1995 (AKG 1996). Mill debris was buried in pits located within the mill area or south of the large impoundment. Debris pits were capped with up to 4 feet of soil (AKG 1996). Decommissioning activities were approved by the Nuclear Regulatory Commission (NRC) on January 28, 1999 by issuance of License Amendment No. 32 (NRC 1999).

1.2.3.3 Removal of Windblown Tailings Contamination Areas

In 1995, HMC completed remediation of contaminated soil adjacent to the LTP, STP and milling facilities. Cleanup criteria for the remediation included 10.5 picocuries per gram (pCi/g) for Ra-226 (ERG 1995) in the top 15 centimeters (cm) of soil and 20 pCi/g Ra-226 at depths greater than 15 cm below the surface. Surface soils from approximately 1,200 acres of land were removed (refer to Figure 1-7). Most of the excavated soils were placed on the eastern side slope of the LTP, but significant quantities were placed on the southern end of the STP and the aprons of the LTP. Subsequent to placement, deposited soils were covered with soil and rock as described in the section below.

1.2.3.4 Placement of Cover Materials

Cover materials were placed on the former mill area, the LTP, and the STP as part of the mill decommissioning efforts completed in the mid-1990s:

- At the STP, 1 foot of cover material was placed in areas outside of Evaporation Pond (EP) 1.
- At the LTP, extensive regrading was completed to fill in the tailings ponds and flatten the side slopes to improve stability. Cover material was placed on the side slopes at a thickness varying from 2 to 3.8 feet. In addition, 6 to 9 inches of rock cover was placed on the side slopes for erosion protection. On the top of the LTP, HMC placed 1 foot of cover material. Since this initial placement, additional cover has been placed on the LTP to fill depressions caused by settlement, to improve drainage, and to address specific areas with elevated radon flux measurements.
- At the former mill area, located southeast of the LTP (refer to Figure 1-1), an average of 2 feet of contaminated soil (containing radium levels above the cleanup standard) was removed following completion of mill demolition. Excavated soils were transported to the east end of the LTP or the south end of the STP for burial. Areas that had been excavated were backfilled with clean alluvial soils. After backfilling, at least 2 feet of clean soil was placed over the entire mill area. Then, rock was applied in a single lift of 2 to 6 inches and mixed with the underlying soil to a depth of not more than two times the rock lift thickness.

Following soil cleanup activities, drainage areas within the Homestake Facility (including areas adjacent to the LTP, mill and ore storage areas, windblown soil cleanup areas, and borrow areas) were regraded and surface channels established for drainage.

1.2.4 Nature and Extent of Contamination within the Homestake Facility

The primary sources of contaminants at the Site are the two tailings piles. The LTP and STP contain approximately 21 million tons and 1.2 million tons of uranium mill tailings, respectively. Throughout most of the mill operations, tailings were deposited after particle size separation by a cyclone operation. Tailings were deposited hydraulically, with progressively finer particles being deposited further away from the cyclone, which was moved along the crest of the embankment, creating overlapping fields of deposition. Thus, no distinct interface existed between the coarse and fine tailings (HMC 1982).

The finer fraction, which generally consisted of silt and clay particles, made up approximately 30 percent of the tailings deposited. The coarse fraction, generally consisting of sand, made up the remaining 70 percent of the tailings (HMC 1982). Based on the Unified Soil Classification System, the finer tailings are classified as silty sand with 13 – 50 percent silt by weight. The coarser tailings are classified as poorly graded sand to silty sand with 5 to 12 percent silt by weight (HMC 2012).

Finer fraction tailings exhibited a higher concentration of radioactive elements than coarser tailings, as displayed in Table 1-1 below.

Table 1-1 Nuclide Concentrations in Deposited Tailings

Contaminant	Fine Tailings	Coarse Tailings
Radium	630 pCi/g	65 pCi/g
Thorium	0.081 pCi/g	0.0116 pCi/g
Lead	840 pCi/g	99 pCi/g
Triuranium octoxide	0.011%	0.004%

Source: HMC 1982
pCi/g = picocuries per gram

1.2.4.1 Groundwater

Uranium, selenium, molybdenum, sulfate, total dissolved solids (TDS), chloride and nitrate concentrations exceed the groundwater quality standards established for the Site. Downward migration of pore water from the tailings piles is a primary source of groundwater contamination at the Site. The extent of groundwater impacts from these contaminants is beyond the LTP. Thorium and Ra-226/228 have impacted the alluvial aquifer below the LTP.

Uranium, selenium, molybdenum, vanadium, sulfate, TDS, and chloride concentrations in the Upper Chinle aquifer exceed mixing zone Site standards below and south of the LTP. In addition, non-mixing zone Site standards for uranium, selenium, molybdenum, sulfate, TDS, and chloride were exceeded in the Upper Chinle aquifer.

In the Middle Chinle mixing zone west of the LTP, uranium, selenium, molybdenum, sulfate, TDS, and nitrate exceed Site standards. In addition, uranium, selenium, and TDS exceed the non-mixing zone Site standards south of the Homestake Facility, with uranium also exceeding mixing zone standards in this area.

Uranium has impacted groundwater in the mixing zone and non-mixing zone of the Lower Chinle aquifer south of the LTP.

1.2.4.2 Soil

The radionuclide(s) of potential concern (ROPCs) identified for soil at the Homestake Facility include uranium, Th-230, Ra-226, and Ra-228. Table 1-2 summarizes the statistic data for each of these ROPCs and includes applicable screening levels.

Table 1-2 Summary of Soil COCs Homestake Facility (pCi/g)

COC	Location	n	Minimum	Maximum	Mean	95% UCL	95% UCL Background[1]
Uranium-234	Surface	27	0.58	18.3	3.7	5.1	1.1
Uranium-238	Surface	27	0.79	19	3.8	5.1	1.2
Ra-226	Surface	50	0.65	9	3.5	4.0	1.8
	Subsurface	25	0.04	9.9	2.4	3.4	NA
Ra-228	Surface	27	0.483	1.71	1.3	1.4	1.1
Th-230	Surface	51	0.1	7.4	2.1	3.1	NA
	Subsurface	25	-0.07	2.9	0.99	1.3	1.4

Notes:
1. EPA 2014
NA = Not available
n = number of observations
COC = chemical of concern
UCL = upper confidence limit

Based on comparison to background, surface soil concentrations uranium-234/238 and Ra-226 are elevated. Ra-228 is also slightly elevated above background. Spatially, there does not appear to be a discernable pattern to the concentrations of these constituents. Soil remediation of much of the Homestake Facility was completed in the early and mid-1990s. The surface soil actions level for the remediation was 10.5 pCi/g of Ra-226, which is above the highest concentration detected at the Site in 2009 (ERG 2014). Other COCs were not analyzed during the remediation.

1.2.4.3 Air

Air particulates are continuously monitored at seven locations around the LTP. The location identified as HMC-6 represents background conditions, and is located due west of the LTP at the westernmost side of the property boundary. Locations HMC-4 and HMC-5 are proximal to the nearest residences and are used to evaluate the equivalent radiation dose received by the public. The evaluation uses quarterly monitoring data for five radionuclides (uranium-238, uranium-234, uranium -235, thorium-230, and radium-226) and is published in Semiannual Environmental Monitoring Reports (HMC 2019b). The equivalent radiation dose at HMC-4 and HMC-5 from Site emissions is estimated by subtracting the dose from background concentrations measured at HMC-6. Based on these calculations, the net annual radiation dose in 2018 from particulates ranged from 0.2 and 0.6 millirems per year (mrem/yr) at HMC-4 and HMC-5 respectively. Compared to the NRC limit for the public of 10 mrem/yr (refer to 10 Code of Federal Regulations (CFR) 20.1101), the equivalent radiation dose attributable to air particulates is relatively small.

The average radon concentration for 2018 at HMC-4 and HMC-5 was 0.89 and 0.84 picocuries per liter (pCi/L) respectively. The average annual concentration at the background location (HMC-16) was 0.34 pCi/L. Subtracting the background concentration from the measured concentrations at HMC-4 and HMC-5 results in net radon concentrations of 0.54 and 0.50 pCi/L respectively. Based on these concentrations, the committed effective dose equivalent at locations HMC-4 and HMC-5 is 41 and 37 mrem/yr respectively for 2018 (HMC 2019b).

An estimate of the radiation dose from direct exposure to radiation sources at the Site is obtained from optically stimulated luminescence dosimeters placed at each monitoring station. The average annual dose in 2018 was calculated at HMC-4 and HMC-5 to be 130 and 131 mrem/yr, respectively. The average annual dose at the background location (HMC-6) was calculated to be 115 mrem/yr. Using a 75 percent occupancy factor, the net annual effective dose equivalent for HMC-4 and HMC-5 was calculated to be 11 and 12 mrem/yr for HMC-4 and HMC-5 respectively (HMC 2019b).

Total Effective Dose Equivalent (TEDE) to the nearest resident is calculated by adding net doses from inhalation of airborne particulate, from the exposure to radon, and from direct gamma radiation. The 2018 TEDE at HMC-4was 52 mrem/yr and at HMC-5 was 50 mrem/yr. These are below the NRC limit of 100 mrem/yr (refer to 10 CFR 20.1301) for public exposure (HMC 2019b).

1.2.5 Human Health Risk Assessment

An evaluation of risks to human health from environmental media Homestake Facility was conducted for the RI. Receptors were selected which represent current land uses and future land uses which are reasonably expected. Tables 1-3 and 1-4 summarize the calculated cancer and non-cancer risks for the selected receptors.

Table 1-3 Cancer Risks Within the Homestake Facility

Receptor	Total Cancer Risk	Inherent Background Risk[1]	Excess Risk Attributable to Site [2]
Future Commercial/Industrial Outdoor Worker	TBD	TBD	TBD
Future Construction Worker	TBD	TBD	TBD
Current Trespasser	TBD	TBD	TBD
Future Trespasser	TBD	TBD	TBD

Notes:

1. Background risk is for background soil ingestion, dermal contact, and inhalation pathways based on background soil exposure point concentration (EPC).
2. Excess risk is the sum of the Site surface soil pathway risks or hazards minus the background risk or hazard for that constituent.

Table 1-4 Non-Cancer Risks Within the Homestake Facility

Receptor	Total Non-Cancer Risk	Inherent Background Risk[1]	Excess Risk Attributable to Site [2]
Future Commercial/Industrial Outdoor Worker	TBD	TBD	TBD
Future Construction Worker	TBD	TBD	TBD
Current Trespasser	TBD	TBD	TBD
Future Trespasser	TBD	TBD	TBD

Notes:

1. Background risk is for background soil ingestion, dermal contact, and inhalation pathways based on background soil EPC.
2. Excess risk is the sum of the Site surface soil pathway risks or hazards minus the background risk or hazard for that constituent. Excess risk for Rn-222 is the sum of the Site air risks-inherent background risk.

Risk to long-term commercial/industrial outdoor workers and construction workers Homestake Facility is above the cancer risk management range. The risk is primarily due to concentrations of Rn-222. Note that while statistically significantly different from background, Site radon EPCs are only 1.2 times higher than background. Once background is factored out, excess risk to the commercial/industrial outdoor worker is below the inherent background risk. For construction workers, risk is also driven by radon in air. Cancer risks to all other receptors for the Homestake Facility are within the risk management range.

Cancer risks are elevated due to radon in air. However, comparison to background concentrations indicated that Site contributions are 1.2 times higher than background.

There are no non-cancer hazard quotients above 1 associated with exposure to media Homestake Facility under the assumptions made in this human health risk assessment.

1.2.6 Baseline Ecological Risk Assessment

The results of the ecological risk analysis were analyzed and interpreted to evaluate the potential for adverse ecological effects and conclude whether or not significant risk exists for each assessment endpoint evaluated. Based on the development of an ecological Site Conceptual Exposure Model for the Site the following relevant potential exposure pathways were identified:

- Potential exposure of vegetation and soil invertebrates by direct contact to constituents in terrestrial habitat Homestake Facility and in the Land Treatment Areas (LTAs);
- Potential exposure of terrestrial avian and mammalian receptors from foraging and through uptake in the food chain to constituents in terrestrial habitat Homestake Facility and in the LTAs; and
- Potential exposure of avian and mammalian receptors by contact to constituents in the on-Site evaporation ponds.

Based on the identification of potentially complete exposure pathways, assessment endpoints and measures of effect were identified. Assessment endpoints contain an entity (e.g., avian population) and an attribute of that entity (e.g., survival rate). The following assessment endpoints and measures of effect were selected for the Baseline Ecological Risk Assessment (BERA):

Soil Assessment Endpoint 1 – Protection and maintenance of terrestrial plant and soil invertebrate communities in Homestake Facility and LTA upland habitat areas.

Soil Measure of Effect 1 – Comparison of maximum concentrations of constituents in soil-to-soil screening values derived for the protection of plants and soil invertebrates.

Soil Assessment Endpoint 2 – Protection and maintenance of terrestrial wildlife receptors within the Homestake Facility and LTA upland habitat areas.

Soil Measure of Effect 2 – Comparison of maximum concentrations of constituents in soil-to-soil screening values derived for the protection of avian and mammalian receptors exposed to soil or to dietary items bioaccumulating analytes from soil.

Evaporation Pond Assessment Endpoint 1 – Protection and maintenance of wildlife receptors that may occasionally ingest water from the evaporation ponds.

Surface Water and Sediment Measure of Effect 1 – Comparison of maximum concentrations of constituents in evaporation pond surface water and sediment to Site specific screening values derived for protection of avian and mammalian receptors.

An initial screening level evaluation (Step 2) identified COCs/ROPCs based on conservative screening level risk estimates.

For soils within the Homestake Facility, soil assessment endpoint 1 (protection of plants and soil invertebrates) and soil assessment endpoint 2 (protection of terrestrial wildlife) were evaluated and the following COCs were identified: lead, molybdenum, selenium, uranium, and vanadium. No individual radionuclides exceeded a hazard quotient of 1; however, radionuclides in aggregate exceeded screening criteria. The following ROPCs were identified: Ra-226, Th-228, Th-230, uranium-234, uranium-238, U natural.

For soils within the LTAs, soil assessment endpoint 1 (protection of plants and soil invertebrates) and soil assessment endpoint 2 (protection of terrestrial wildlife) were evaluated and the following COCs were identified: lead, selenium, uranium, and vanadium. No ROPCs were identified as exceeding screening criteria.

Evaporation pond assessment endpoint 1 (protection of wildlife that may occasionally drink water from the evaporation ponds) was evaluated and the following COCs in sediment were identified: molybdenum and vanadium. No sediment ROPCs were identified.

Evaporation pond surface water was evaluated and the following COCs/ROPCs were identified: molybdenum, selenium, and uranium, radium-226, thorium-228, and thorium-230.

For this BERA, further evaluation (Step 3a) refined the COC/ROPC selection process using more Site specific assumptions for exposure concentrations and ecological effects. The following sections summarize the results of the Step 3a evaluation and conclude with Scientific/Management Decision Point (SMDP) statements.

1.2.6.1 Soil within the Homestake Facility

COCs and ROPCs were evaluated for receptor-specific exposure in a food web model. No Observed Adverse Effect Levels (NOAEL) hazard quotients (HQs) exceed 1 for the following receptors:

- Scaled quail – selenium and vanadium
- Western kingbird – selenium and vanadium
- Kangaroo rat - molybdenum and selenium
- Deer mouse - molybdenum and selenium

No Lowest Observed Adverse Effect Levels (LOAEL) HQs exceed 1. The American kestrel was selected as a surrogate for protected species (migratory birds, bald eagles) potentially passing through the area. NOAEL HQs do not exceed 1 for any COPCs for the American kestrel. Based on these findings, exposure to soil at the Homestake Facility is not expected to result in unacceptable risks to terrestrial receptors.

1.2.6.2 Soil within Land Treatment Areas

COPCs and ROPCs were evaluated for receptor-specific exposure in a food web model. As shown in Tables 5-546 through 5-5961, NOAEL HQs exceed 1 for the following receptors:

- Western kingbird – vanadium
- Kangaroo rat - selenium
- Deer mouse - selenium

No LOAEL HQs exceed 1. The American kestrel was selected as a surrogate for protected species (migratory birds, bald eagles) potentially passing through the area. As shown in Table 5-568, NOAEL HQs do not exceed 1 for any COPCs for the American kestrel. Based on these findings, exposure to soil in the LTAs is not expected to result in unacceptable risks to terrestrial receptors.

1.2.6.3 Evaporation Ponds

COPCs were evaluated for receptor-specific exposure. Manganese and selenium in evaporation pond surface water had HQs below 1 for all species and are not expected to result in unacceptable risks to terrestrial receptors.

NOAEL HQs exceed 1 for the following all receptors for molybdenum and uranium.

LOAEL HQs exceed 1 for the following receptors.

- Scaled quail – molybdenum
- American robin –molybdenum
- American kestrel – molybdenum
- Ord's-Kangaroo rat - molybdenum, uranium
- Deer mouse – molybdenum, uranium
- Kit fox - molybdenum, uranium

Acute HQs exceed 1 for the following receptors.

- Ord's-Kangaroo rat - molybdenum
- Deer mouse – molybdenum

Because the acute HQ is below 1, uranium in evaporation pond surface water is not expected to result in unacceptable risks to terrestrial receptors. Additional evaluation of the uncertainties and assumptions is needed prior to making a conclusion regarding ecological effects from evaporation pond exposure to molybdenum.

For ROPCs, UCL95 EPCs for radium-226, radium-228, and thorium-230 in evaporation pond surface water are below receptor-specific no effect RESLs, and the sum of fractions is less than 1.

HQs are greater than 1 for the American robin (representing herbivorous, ominivorous, and insectivorous birds) for Ra-226 and uranium as represented by U-natural activity. HQs for uranium for the deer mouse also exceed 1. The Los Alamos National Laboratory (LANL) Ecorisk Database (LANL 2019) reports radioecological screening levels (RESLs) which can be used to compute HQs. Dividing maximum concentrations of the ROPCs by the LANL RESLs yielded HQs of 1 or less.

1.2.6.4 BERA Conclusion

SMDP: There is adequate information to conclude that, despite some uncertainties, ecological risks are negligible overall for plant and invertebrate and vertebrate wildlife receptors that may come into contact with site-related constituents in soil and surface water. Therefore, remediation on the basis of ecological risk is not recommended.

1.3 Applicable or Relevant and Appropriate Requirements (ARARs)

Remedial actions are intended to be protective of human health and the environment. Section 121 of CERCLA requires that primary consideration be given to remedial alternatives that attain or exceed ARARs. The purpose of this requirement is to make CERCLA response actions consistent with other pertinent regulatory requirements at both the Federal and State levels. Applicable requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that directly apply to the management of hazardous substances at CERCLA sites. Relevant and appropriate requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law, which while not "applicable," address problems or situations sufficiently similar to those encountered at a CERCLA site, that their use is well suited or appropriate to the particular site. In addition to ARARs, to be considered (TBC) criteria are non-promulgated, non-enforceable guidelines or criteria that may be useful for developing an interim remedial action, or are necessary for evaluating what is protective of human health and/or the environment. Examples of TBC criteria include the USEPA Drinking Water Health Advisories, Reference Doses, and Cancer Slope Factors.

ARARs are grouped into three types: chemical-specific, action-specific, and location-specific. Chemical-specific ARARs include laws and requirements that establish health- or risk based numerical values or methodologies for environmental contaminant concentrations or discharge. Chemical-specific ARARs and TBC criteria for the Site are listed in Table 1-5.

Action-specific ARARs regulate the specific type of action or technology under consideration, or the management of regulated materials. Location-specific ARARs are requirements that relate to Site geography. Action-specific and location-specific ARARs and TBC criteria for the Site are also listed in Table 1-5.

Table 1-5 Applicable or Relevant and Appropriate Requirements

Chemical-Specific Applicable or Relevant and Appropriate Requirements (ARARs) and "to be considered" (TBC) Criteria			
Media	**Requirement**	**Requirement Synopsis**	**Determination and Rationale**
FEDERAL REQUIREMENTS			
Radioactive Material	**Nuclear Regulatory Commission (NRC) License SUA-1471**	NRC License SUA-1471 provides chemical specific requirements establishing clean-up levels at the Site. Specifically: License Condition 35(B) provides groundwater protection standards applicable to the site. License Condition 36(A)(3) establishes radon emission limitation at an average flux no greater than 20 picocuries per meters squared-second (pCi/m^2s) to be achieved by the radon barrier. License Condition 37(C) establishes a radon activity limit of 5 pCI/g above background of the radon barrier material. License Condition 38 establishes a limit of 30 pCi/l combined radium for the collection water, above which an impact evaluation is required.	Applicable as to License Conditions 36(a)(3), 37(C), and 38. License Condition 35(B) is potentially applicable unless waived as technically impracticable, an alternative abatement standard is adopted, or the standard is otherwise determined to be inapplicable.
Radioactive Material	**Domestic Licensing of Source Material — Criteria Relating to the Operation of Uranium Mills and the Disposition of Tailings or Wastes Produced by the Extraction or Concentration of Source Material from Ores Processed Primarily for Their Source Material Content** 10 Code of Federal Regulations (CFR) Part 40 Appendix A, Criteria 5B, 6, and 13	Establishes (i) concentration limits to be used for groundwater protection at uranium mill tailings sites and (ii) limits on the levels of radioactive materials from surface impoundments	Applicable as implemented in NRC License SUA-1471 as to limits on the levels of radioactive materials from surface impoundments. Concentration limits for groundwater are potentially applicable unless waived as technically impracticable, an alternative abatement standard is adopted, or the standard is otherwise determined to be inapplicable.

Table 1-5 Applicable or Relevant and Appropriate Requirements (Con't)

Chemical-Specific ARARs and TBC Criteria			
Media	**Requirement**	**Requirement Synopsis**	**Determination and Rationale**
FEDERAL REQUIREMENTS			
Residual Radioactive Material	**Uranium Mill Tailings Radiation Control Act of 1978 (UMTRCA), as amended** Regulations at 40 CFR§ 192.2 Subpart A – Standards for the Control of Residual Radioactive Materials from Inactive Uranium Processing Sites	Provides design requirements for the control of residual radioactive material at 'designated processing or depository sites'. Requires designed controls to: (a) be effective for up to 1,000 years, to the extent reasonably achievable, and, in any case, for at least 200 years; and (b) provide reasonable assurance that releases of radon-222 will not exceed an average (over the entire site surface) release rate of 20 picocuries per square meter per second (pCi/m^2s), or increase the annual average concentration of radon-222 in air at or above any location outside the disposal site by more than one-half picocurie per liter (pCi/L). Also requires that the site be designed and stabilized in a manner that minimizes the need for future maintenance.	Applicable

Table 1-5 Applicable or Relevant and Appropriate Requirements (Con't)

Chemical-Specific ARARs and TBC Criteria			
Media	**Requirement**	**Requirement Synopsis**	**Determination and Rationale**
FEDERAL REQUIREMENTS			
Residual Radioactive Material	**UMTRCA, as amended** Regulations at 40 CFR§ 192.2 Subpart B – Standards for the Cleanup of Land and Buildings Contaminated with Residual Radioactive Materials from Inactive Uranium Processing Sites	40 CFR §192.12(a) provides that the concentration of radium-226 in land averaged over 100 square meters must not exceed background by more than: (1) 5 picocuries per gram (pCi/g) averaged over the first 15 centimeters (cm) of soil below surface; and (2) 15 pCi/g averaged over 15 cm thick layers of soil more than 15 cm below surface. 40 CFR §192.12(b)(1) provides design criteria for remedial actions that address the level of gamma radiation in an occupied or habitable building. It provides that the objective of the remedial action shall be to achieve an annual average radon decay product concentration (including background) not to exceed 0.02 Working Level (WL). And in any case, the radon decay product concentration (including background) may not exceed 0.03 WL and may not exceed the background level by more than 20 microroentgens per hour.	Applicable

Table 1-5 Applicable or Relevant and Appropriate Requirements (Con't)

Chemical-Specific ARARs and TBC Criteria			
Media	**Requirement**	**Requirement Synopsis**	**Determination and Rationale**
FEDERAL REQUIREMENTS			
Residual Radioactive Material	**UMTRCA, as amended —** Regulations at 40 CFR§ 192.2 Subpart C – Implementation	40 CFR §192.20 details implementation of Subparts A and B. 40 CFR §192.21 provides that the supplemental standards in 40 CFR §192.22 may be used in certain cases in lieu of the standards in Subparts A and B. For example, 40 CFR §192.22 specifies supplemental standards that may be used if radionuclides other than radium-226 and its decay products are present in sufficient quantity and concentration to constitute a significant radiation hazard from residual radioactive materials. In such a situation, 40 CFR §192.22(b) specifies that "remedial actions shall reduce other residual radioactivity to levels that are as low as is reasonably achievable (ALARA) and conform to the standards of subparts A and B to the maximum extent practicable."	Applicable

Table 1-5 Applicable or Relevant and Appropriate Requirements (Con't)

Chemical-Specific ARARs and TBC Criteria			
Media	**Requirement**	**Requirement Synopsis**	**Determination and Rationale**
FEDERAL REQUIREMENTS			
Uranium Byproduct Material	**UMTRCA, as amended —** Regulations at 40 CFR§ 192 Subpart D – Standards for the Management of Uranium Byproduct Materials 40 CFR§ 192.32(a)(1) and (2) and § 192.32(b)(1) and (2)	Protect the public and the environment from uranium mill tailings prior to closure and post- closure. 192.32(a) (1) provides standards for construction and installation of surface impoundments. 192.32(a) (2) provides criteria for establishing groundwater protection levels for uranium byproduct materials at Title II sites. 192.32(b)(1) provides standards for post closure radon emissions from byproduct material limiting releases of radon-222 from uranium byproduct materials to not exceed an average release rate of 20 pCi/m^2s. 192.32(b)(2) provides exemption from standards in 192.32(b)(1) for disposal sites which are not above specified levels (radium-226 not above background level by more than 5 pCi/g, averaged over the first 15 cm below surface and 15 pCi/g, averaged over 15 cm thick layers more than 15 cm below the surface).	Applicable
Air	**Clean Air Act (CAA) — National Emission Standards for Hazardous Air Pollutants (NESHAPs)** 40 CFR § 61.92 (part of Subpart H)	Regulates airborne emissions of radionuclides from Department of Energy (DOE) facilities to nearest off-site receptor—emissions of radionuclides cannot exceed 10 milli-Roentgen-Equivalent-Man per year (mrem/yr)	Relevant and appropriate because DOE will ultimately take ownership of and be responsible for long-term management of the site

Table 1-5 Applicable or Relevant and Appropriate Requirements (Con't)

Media	Requirement	Requirement Synopsis	Determination and Rationale
Chemical-Specific ARARs and TBC Criteria			
FEDERAL REQUIREMENTS			
Air	**CAA** —NESHAPs 40 CFR § 61.192 (part of Subpart Q)	Regulates airborne emissions of radon from DOE facilities—a facility shall emit no more than 20 picocuries per square meter per second [pCi/(m^2 - sec) (1.9 pCi/(ft^2 - sec)] of radon-222 as an average for the entire source, into the air	Relevant and appropriate because DOE will ultimately take ownership of and be responsible for long-term management of the site.
Air	**CAA - NESHAPs** 40 CFR § 61.252(a) (part of Subpart W)	Regulates airborne emissions of radon from facilities licensed to manage uranium byproduct materials during and following the processing of uranium ores, commonly referred to as uranium mills and their associated tailings. Does not apply to the disposal of tailings. Radon-222 emissions to the ambient air from an existing uranium mill tailings pile shall not exceed 20 picocuries per square meter per second [pCi/(m2 -sec) (1.9 pCi/(ft2 - sec)	Applicable
STATE REQUIREMENTS			
Air	**New Mexico Air Quality Control Act (Emission Standards for Hazardous Air Pollutants)** § 20.2.78.9 New Mexico Administrative Code (NMAC) - Adoption of 40 CFR Part 61	Adopts federal NESHAPs promulgated in 40 CFR Part 61	Applicable—See federal standards incorporated above
Water	**New Mexico Water Quality Act (Ground and Surface Water Protection)** § 20.6.2.2101 NMAC — Surface Water General Requirements	Prohibits discharges to a watercourse if the effluent exceeds specific limits on biochemical oxygen demand, chemical oxygen demand, settleable solids, fecal coliform, and pH	Applicable to any discharge to a "watercourse"

Table 1-5 Applicable or Relevant and Appropriate Requirements (Con't)

Chemical-Specific ARARs and TBC Criteria			
Media	**Requirement**	**Requirement Synopsis**	**Determination and Rationale**
STATE REQUIREMENTS			
Water	**New Mexico Water Quality Act (Ground and Surface Water Protection)** § 20.6.2.3103 NMAC — Standards for Ground Water of 10,000 milligrams per liter (mg/L) Total Dissolved Solids (TDS) Concentration or Less	Establishes contaminant-specific standards for groundwater of 10,000 mg/L or less TDS or, in the alternative, adopts existing conditions if existing conditions exceed the standards promulgated therein.	Applicable as to all constituents' standards except for molybdenum and uranium. Molybdenum and uranium standards are potentially applicable unless waived as technically impracticable, an alternative abatement standard is adopted, or the standard is otherwise determined to be inapplicable.
Water	**New Mexico Water Quality Act (Ground and Surface Water Protection)** **§ 20.6.2.4103(A)-(D) NMAC — Abatement Standards and Requirements**	Requires abatement of (i) groundwater pollution at any place of withdrawal for present or reasonably foreseeable future use, where the TDS concentration is 10,000 mg/L or less, to conform to standards defined in § 20.6.2.3101 NMAC and (ii) surface water pollution to conform to the Water Quality Standards for Interstate and Intrastate Streams in New Mexico (§ 20.6.4 NMAC).	Applicable
Water	**New Mexico Water Quality Act (Standards for Interstate and Intrastate Surface Waters)** **§ 20.6.4.8.A(1) NMAC — Antidegradation Policy and Implementation Plan for Surface Water**	Requires that existing instream water uses are maintained and protected and that no further water quality degradation occur that would interfere with or become injurious to existing uses	Potentially applicable to the extent the facility has potential to impact surface waters of the state

Table 1-5 Applicable or Relevant and Appropriate Requirements (Con't)

Chemical-Specific ARARs and TBC Criteria			
Media	**Requirement**	**Requirement Synopsis**	**Determination and Rationale**
STATE REQUIREMENTS			
Water	**New Mexico Water Quality Act (Standards for Interstate and Intrastate Surface Waters)** **§ 20.6.4.13 NMAC — Water Quality General Criteria**	General Surface Water Criteria — Narrative criteria applicable to all surface water at all times, unless a specific standard is provided elsewhere in these regulations	Potentially applicable to the extent the facility has potential to impact surface waters of the state
Water	**New Mexico Water Quality Act (Standards for Interstate and Intrastate Surface Waters)** § 20.6.4.98 NMAC — Intermittent Waters § 20.6.4.900 A, C, D, F, G, H2 NMAC — Criteria Applicable to Existing, Designated or Attainable Uses	Establishes water quality designated use and criteria for all non-perennial unclassified waters of the state	Potentially applicable to the extent the facility has potential to impact non-perennial unclassified waters of the state

Table 1-5 Applicable or Relevant and Appropriate Requirements (Con't)

Action-Specific ARARs and TBC Criteria			
Media	**Requirement**	**Requirement Synopsis**	**Determination and Rationale**
FEDERAL REQUIREMENTS			
Radioactive Material	**NRC License SUA-1471**	Establishes standards for conducting work at the site, including: License Condition 14 requires release of equipment or packages from the restricted area to be in accordance with the attachment to SUA-1471, "Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses for Byproduct or Source Materials" License Condition 16 requires that an environmental evaluation of any activity not previously assessed by the NRC be completed and approved by NRC before engaging in the activity. License Condition 17 requires that transfer of title of byproduct material and land be made to the United States or the State of New Mexico prior to termination of the license. License Condition 22 requires that all documentation required by the license be maintained for a period of at least 5 years. License Condition 24 requires a Radiation Work Permit for all work or nonroutine maintenance jobs with potential for exposure to radioactive material. License Condition 26 provides limitations on transfers of mill tailings from the site. License Condition 28 provides conditions for an NRC-approved financial surety arrangement.	Applicable

Table 1-5 Applicable or Relevant and Appropriate Requirements (Con't)

Action-Specific ARARs and TBC Criteria			
Media	**Requirement**	**Requirement Synopsis**	**Determination and Rationale**
FEDERAL REQUIREMENTS			
Radioactive Material	**NRC License SUA-1471 (Con't)**	License Condition 32 provides corrective action requirements applicable if worker radiation occupational exposure exceeds certain limits. License Condition 35(A), (C) and (D) establish requirements for groundwater restoration project including implementation of a groundwater monitoring program, implementation of a corrective program including operation of the RO plant and lined evaporation ponds and enhanced evaporation systems, and monthly sampling at Sample Point 2 downstream of the mixing tank. License Condition 35(E) requires an annual performance review of the corrective action program submitted by March 31 of each year. License Condition 36(A) (3) requires a final radon barrier placement over the entire tailings pile completed within 2 years of completion of groundwater corrective actions. License Condition 36(E) requires performing an annual radon flux survey for the LTP and STP during the milestone extension period submitted by March 31 of each year.	Applicable

Table 1-5 Applicable or Relevant and Appropriate Requirements (Con't)

Action-Specific ARARs and TBC Criteria			
Media	**Requirement**	**Requirement Synopsis**	**Determination and Rationale**
FEDERAL REQUIREMENTS			
Radioactive Material	**NRC License SUA-1471 (Con't)**	License Conditions 37 and 38 provide the conditions and criteria applicable to the placement of the interim cover and final radon barrier at the LTP and STP, including providing a completion report within 6 months of completion of reclamation, conducting soil cleanup verification, and conducting semi-annual sampling of collection water. License Condition 41 requires that documentation on unplanned release of source or byproduct materials and process chemicals be maintained, evaluated, and reported, if required. License Condition 42 requires submittal of an annual report to NRC that includes the ALARA audit report, land use survey, monitoring data, corrective action program report, and effluent and environmental monitoring reports.	Applicable
Uranium Byproduct Material/ Placement of radon barrier	**UMTRCA**, as amended — Regulations at 40 CFR § 192.32(a)(3) and (4)	Protect the public and the environment from uranium mill tailings piles and impoundments that are nonoperational through the placement of a permanent radon barrier. Provides construction standards and monitoring requirements.	Applicable
Uranium Byproduct Material and Residual Non-Radioactive Material/End of closure period	**UMTRCA**, as amended — Regulations at 40 CFR § 192.32(b)(1) and (2)	Protect the public and the environment from nonradiological and radiological hazards. Provides standards for design and monitoring to be effective for one thousand years, and limit release of radon-222 from uranium byproduct materials to not exceed an average release rate of 20 pCi/m^2s.	Applicable

Table 1-5 Applicable or Relevant and Appropriate Requirements (Con't)

Action-Specific ARARs and TBC Criteria			
Media	**Requirement**	**Requirement Synopsis**	**Determination and Rationale**
FEDERAL REQUIREMENTS			
Radioactive Material/Uranium mill tailings impoundment operation, closure and remediation	**License Requirements for Land Disposal of Radioactive Waste** Regulations at 10 CFR Part 40 Appendix A, Criteria 4, 5, 6, 6A, 9, 10, 11 and 12	Criteria relating to the disposition of tailings or wastes produced by the extraction or concentration of source material from ores processed primarily for their source material content	Applicable
Radioactive Material/Any activities conducted under an NRC license	**Standards for Protection Against Radiation** Regulations at 10 CFR Part 20: Subpart C — Occupational dose limits for adults and minors Subpart D — Dose limits for individual members of the public Subpart E — Criteria for license termination Subpart G — Control of exposure from external sources in restricted areas Subpart H — Respiratory protection and controls to restrict internal exposure in restricted areas Subpart I — Storage and control of licensed material Subpart K — Waste Disposal	Establish standards for protection against ionizing radiation resulting from activities conducted under licenses issued by the Nuclear Regulatory Commission	Applicable

Table 1-5 Applicable or Relevant and Appropriate Requirements (Con't)

Action-Specific ARARs and TBC Criteria			
Media	**Requirement**	**Requirement Synopsis**	**Determination and Rationale**
FEDERAL REQUIREMENTS			
Water/ Stormwater discharges to waters of the United States	**Clean Water Act (CWA)** Section 402, National Pollutant Discharge Elimination System 40 CFR: § 122.41 § 122.42(a) § 122.42(d) § 122.44(a)(1) § 122.44(e) § 122.44(i)(4) § 122.44(k)(2) and (k)(4)	On-site discharges from site are required to meet the substantive CWA requirements, including discharge limitations and best management practices	Substantive requirements are relevant and appropriate to the extent there are discharges of a pollutant to waters of the United States
Water/ Stormwater discharges to waters of the United States	**CWA** Section 402, National Pollutant Discharge Elimination System (NPDES) Technology-based Treatment Requirements in Permits— 40 CFR §125.3(c)(3) §125.3(d)(1), (2) and (3) §125.3(e) §125.3(f) §125.3(h)	On-site discharges from site are required to meet the substantive CWA requirements, including discharge limitations, monitoring and best management practices	Substantive requirements are relevant and appropriate to the extent there are discharges of a pollutant to waters of the United States
STATE REQUIREMENTS			
Air/Burning weeds associated with land treatment activities	**New Mexico Air Quality Control Act (Open Burning)** § 20.2.60.111 NMAC —Open Burning of Vegetative Material	Establishes open burning restrictions and requirements	Applicable to the extent open burning activities are conducted at the site

Table 1-5 Applicable or Relevant and Appropriate Requirements (Con't)

Action-Specific ARARs and TBC Criteria			
Media	**Requirement**	**Requirement Synopsis**	**Determination and Rationale**
STATE REQUIREMENTS			
Air/Use of diesel-powered vehicles and stationary combustion equipment at the site	**New Mexico Air Quality Control Act (Smoke and Visible Emissions)** § 20.2.61.109-.112 NMAC	Establishes smoke and visible emissions restrictions for stationary combustion equipment, diesel-powered vehicles, and diesel-powered locomotives	Applicable if stationary combustion equipment or diesel-powered vehicles are used at the site
Water/ Mitigation of groundwater contamination	**New Mexico Water Quality Act (Ground and Surface Water Protection)** § 20.6.2.1203 NMAC — Notification of Discharge-Removal	Requires persons to take such corrective actions as are necessary to contain and remove or mitigate a discharge of oil or other water contaminant with the potential to be detrimental to human health, animal or plant life, or property.	Relevant and appropriate
Water/Use of underground injection control wells	**New Mexico Water Quality Act (Ground and Surface Water Protection)** § 20.6.2.5004(4) and 5006 NMAC — Prohibited Underground Injection Control Activities and Wells	Underground Injection Control to protect all groundwater of the State of New Mexico which has an existing concentration of 10,000 mg/l or less TDS for present and potential future use as domestic and agricultural water supply, and to protect those segments of surface waters which are gaining because of groundwater inflow for uses designated in the NMWQCC standards.	Relevant and appropriate, substantive requirements are applicable as implemented by NMED Homestake Mining Company Discharge Permit (DP-200).
Groundwater Abatement Activities	**New Mexico Environment Department Homestake Mining Company Discharge Permit No. 200 (DP-200)**	Regulates groundwater contamination abatement activities at the site, including injection of contaminated alluvial groundwater to tailings piles, operation of collection and evaporation ponds, extraction and reverse osmosis system, pilot testing of alternate groundwater treatment technologies, including ex-situ zeolite bed and EC, and in-situ TPP uranium fixation.	TBC for injection of water from the San Andres – Glorietta formation and reverse osmosis treated ground water from the San Mateo and Chinle Formation.

Table 1-5 Applicable or Relevant and Appropriate Requirements (Con't)

Action-Specific ARARs and TBC Criteria			
Media	**Requirement**	**Requirement Synopsis**	**Determination and Rationale**
STATE REQUIREMENTS			
Groundwater Abatement Activities	**New Mexico Environment Department Homestake Mining Company Discharge Permit No. 200 (DP-200) (Con't)**	Specific Permit Conditions include: 1. Abatement groundwater contamination through operation of all existing and future permitted abatement systems to control and collect contaminated groundwater impacted by Site in accordance with IV. Specific Permit Conditions 1-4. 2. Operate alternate groundwater treatment technologies in accordance with IV. Specific Permit Conditions 5-7. 3. Operate Reverse Osmosis system in accordance with IV. Specific Permit Conditions 8 and 9. 4. Inject compliant water into contaminated aquifers in accordance with IV. Specific Permit Condition 10. 5. Operate LTP seepage and flushing in accordance with IV. Specific Permit Conditions 11 and 12. 6. Ensure low-concentration inject does not exceed specified concentration limits. 7. Conduct monthly discharge quantity monitoring in accordance with IV. Specific Permit Condition 24.	TBC for injection of water from the San Andres – Glorietta formation and reverse osmosis treated ground water from the San Mateo and Chinle Formation.

Table 1-5 Applicable or Relevant and Appropriate Requirements (Con't)

Action-Specific ARARs and TBC Criteria			
Media	**Requirement**	**Requirement Synopsis**	**Determination and Rationale**
STATE REQUIREMENTS			
Groundwater Abatement Activities	**New Mexico Environment Department Homestake Mining Company Discharge Permit No. 200 (DP-200) (Con't)**	8. Notify NMED of changes in location of injection wells, infiltration lines, anticipated plugging and abandonment of monitoring wells and implement post-closure monitoring in accordance with IV. Specific Permit Conditions 26-28. 9. Conduct treatment system monitoring in accordance with IV. Specific Permit Conditions 29 and 30, for specified constituents. 10. Conduct collection and evaporation pond monitoring in accordance with IV. Specific Permit Conditions 31-35. 11. Conduct monitoring of former land application areas in accordance with IV. Specific Permit Conditions 36-39. 12. Conduct facilities monitoring in accordance with IV. Specific Permit Conditions 40-43. 13. Complete reporting and notifications in accordance with IV. Specific Permit Conditions 44-52. 14. Conduct site closure and post-closure monitoring in accordance with IV. Specific Permit Conditions 56-61. 15. Maintain records in accordance with IV. Specific Permit Conditions 65-68.	TBC for injection of water from the San Andres – Glorietta formation and reverse osmosis treated ground water from the San Mateo and Chinle Formation.

Table 1-5 Applicable or Relevant and Appropriate Requirements (Con't)

Action-Specific ARARs and TBC Criteria			
Media	**Requirement**	**Requirement Synopsis**	**Determination and Rationale**
STATE REQUIREMENTS			
Water/Drilling new injection and withdrawal wells	**New Mexico Regulations Governing Well Driller Licensing; Construction, Repair, and Plugging of Wells** § 19.27.4.29 NMAC — Well Drilling – General Requirements § 19.27.4.30 NMAC — Well Drilling – Non-Artesian (Unconfined) Well Requirements	Establishes rules and regulations governing construction, repair and plugging of wells and boreholes.	Applicable
Water/Operating dams associated with evaporation and the STP	**New Mexico Statutes and Regulations Governing Dam Design, Construction and Dam Safety** § 19.25.12 NMAC	Standards for the design and construction of all jurisdictional dams in New Mexico intended to facilitate the continued safe operation and maintenance of all non-federal jurisdictional dams.	Applicable, as implemented by permits issued by the New Mexico State Engineer for the construction of evaporation ponds (3), and the STP.
Hazardous Waste/ Petroleum storage tanks	**New Mexico Regulations Governing Petroleum Storage Tanks** § 20.5 NMAC	Provides for regulation of underground and aboveground petroleum storage tanks and remediation for spills and leaks.	Applicable if petroleum storage tanks are present.

Table 1-5 Applicable or Relevant and Appropriate Requirements (Con't)

Location-Specific ARARs and TBC Criteria			
Media	**Requirement**	**Requirement Synopsis**	**Determination and Rationale**
FEDERAL REQUIREMENTS			
Cultural Resources	**NRC License SUA-1471**	License Condition 43 requires completion of a cultural resource inventory before engaging in development activity not previously assessed by NRC and that all disturbances to comply with National Historic Preservation Act and Archaeological Resources Protection Act.	Applicable
Cultural Resources	**The Native American Graves Protection And Repatriation Act** 25 United States Code (USC) Section 3001 *et seq* and its regulations Title 43 CFR Part 10	Protects Native American graves from desecration through the removal and trafficking of human remains and cultural items including funerary and sacred objects	Substantive requirements applicable if Native American burials or cultural items are identified within area to be disturbed
Cultural Resources	**National Historic Preservation Act** 16 USC 470 *et seq;* 36 CFR Part 800	Provides for the protection of sites with historic places and structures	Substantive requirements applicable if eligible resources identified within area to be disturbed
Cultural Resources	**Archeological Resources Protection Act of 1979** 16 USC Sections 47000-47011; 43 CFR Part 7	Prohibits removal of or damage to archaeological resources unless by permit or exception	Substantive requirements applicable if eligible resources are identified within area to be disturbed
Cultural Resources	**American Indian Religious Freedom Act** 42 USC Section 1996 *et seq.*	Protects religious, ceremonial, and burial sites, and the free practice of religions by Native American groups	Substantive requirements applicable if Native American sacred sites are identified within area to be disturbed
Threatened and Endangered Species	**Endangered Species Act** 7 USC Section 136; 16 USC Sections 15331-1548, Title 50 CFR Parts 17 and 402	Regulates the protection of threatened and endangered species or critical habitat of such species	Substantive requirements applicable if protected species are identified within area to be disturbed
Migratory Birds	**Migratory Bird Treaty Act** 16 USC Sections 703-712	Regulates the protection of migratory birds	Substantive requirements applicable if migratory birds are present at the site.

Table 1-5 Applicable or Relevant and Appropriate Requirements (Con't)

Location-Specific ARARs and TBC Criteria			
Media	**Requirement**	**Requirement Synopsis**	**Determination and Rationale**
STATE REQUIREMENTS			
Threatened and Endangered Species	**New Mexico Wildlife Conservation Act** New Mexico Statutes Annotated (NMSA) 1978, §§ 17-2-37 to -46	Provides for the regulation and protection of threatened and endangered species	Substantive requirements applicable if protected species are identified within the area to be disturbed
Threatened and Endangered Species	**New Mexico Endangered Plant Species Act** NMSA 1978, § 75-6-1	Provides for the regulation and protection of threatened and endangered plant species. Endangered plant species means any plant species whose prospects of survival within the state are in jeopardy or are likely within the foreseeable future	Substantive requirements applicable if protected species are identified within the area to be disturbed
Threatened and Endangered Species	**New Mexico Endangered Plant Regulations** § 19.21 NMAC	Establishes requirements for the protection of threatened and endangered flora and fauna	Substantive requirements applicable if protected species are identified and within the area to be disturbed
Cultural Resources	**New Mexico Cultural Properties Act** NMSA 1978, §§ 18-6-1 through 18-6-27	Provides for the preservation, protection, and enhancement of structures, sites, and objects of historical significance within the state	Substantive requirements applicable if protected areas are identified within the area to be disturbed
Cultural Resources	**New Mexico Prehistoric and Historic Sites Preservation Act** NMSA 1978, §§ 18-8-1 through 18-8-8	Provides for the acquisition, stabilization, restoration or protection of significant prehistoric or historic sites	Substantive requirements applicable if protected areas are identified within the area to be disturbed
Cultural Resources	**New Mexico Prehistoric and Historic Sites Regulations** § 4.10.12 NMAC	Provides for the implementation of the Act	Substantive requirements applicable if protected areas are identified within the area to be disturbed
Water Discharges	**New Mexico Water Quality Act (Standards for Interstate and Intrastate Surface Waters)** § 20.6.4.122 NMAC — Rio Grande Basin	Establishes water quality designated use and criteria for a specific stream segment (San Mateo Creek Basin).	Applicable - If proposed action involves a discharge to the San Mateo Creek Basin

1.4 Remedial Action Objectives

Under the National Contingency Plan, Remedial Action Objectives (RAOs) are established to specify “contaminants and media of concern, potential exposure pathways, and remediation goals” (40 CFR §300.430(e)(2)(i)). RAOs provide a foundational consideration in the process of comparing remedial alternatives and help to focus the development and evaluation of alternatives. Preliminary RAOs are described below. RAOs typically evolve over the course of the RI/FS process and become final only when the record of decision is signed.

RAO1 – Restore groundwater quality in those portions of the alluvial, Upper Chinle, Middle Chinle, and Lower Chinle aquifers that have been impacted by seepage from the LTP.

RAO2 – Reduce Rn-222 emissions from the LTP.

RAO1 addresses OU1 while RAO2 addresses OU2.

SECTION 2 AREAS AND VOLUMES OF CONTAMINATED MEDIA

The primary sources of contaminants at the Site are the two tailings piles. Debris from the mill operating facilities, which is buried south of the tailings piles is also a primary source of contamination. Comparatively, the buried debris pits are much smaller than the tailings piles.

As described in Section 1.2, the LTP and STP contain approximately 21 million tons and 1.2 million tons of uranium mill tailings, respectively. Tailing were deposited using hydrocyclone equipment. Hydrocycloning resulted in heterogeneous deposition of tailings: the coarse fraction comprised of mostly of sand, was generally deposited on the outer edges of the pile; the fine fraction comprised of mostly of silt, was deposited in the center. Based on the estimated average density of the tailings (96 pounds per cubic foot), the volume of tailings in the LTP and STP is about 16.2 million cubic yards and 926,000 cubic yards, respectively (HMC 1982).

Seepage from the LTP, which was deposited at an elevation above the groundwater table, is the source of groundwater contamination from the Site. The volume of seepage that could be drained from the LTP was estimated at 184 million gallons in 1994, prior to the installation of dewatering wells designed to accelerate the draindown of seepage from the LTP. In 2000, prior to the start of the flushing program, the drainable volume was estimated to be 125 million gallons (Hoffman and Cox, 2003). Because of the heterogeneous deposition of the tailing, the rate of seepage draindown across the LTP is highly variable. Based on mass removal analysis, the estimated dissolved uranium mass remaining in the plume in 2009 was 30,000 kg, compared to an estimated dissolved mass in the plume of 80,000 kg, in 2001 (HMC 2012).

As previously stated, radon concentrations in air at the Site are above measured background concentrations. There could be several off-site sources of radon contributing to radon concentrations including naturally occurring mineralized soil and outcroppings of rock; and anthropogenic waste rock piles associated with legacy uranium mines. HMC has modeled on-site sources of radon to predict radon concentrations at site monitoring locations. On-site radon sources modeled include the top of the LTP, the sides of the LTP, the side slopes of the STP, the southern portion of the STP, EP-1, EP-2, and the RO treatment system. Based on this modeling, approximately 80% of the on-site radon emissions are from the top of the LTP (HMC 2013).

SECTION 3 TREATABILITY STUDIES

HMC has evaluated or is currently evaluating alternative technologies and remedy enhancements for ground water treatment at the Site under the NRC Source Materials License SUA-1471. The following candidate technologies have been identified and studied for possible implementation at the Site:

- Tripolyphosphate treatment
- Electrocoagulation treatment
- In-Situ Biological Treatment

Results of studies for each of these candidate technologies was evaluated on the basis of effectiveness, implementability, cost, and predicted results of a full-scale system. The following sections provide a summary of the pilot studies and the evaluation.

3.1 Tripolyphosphate Treatment

Pilot studies for in situ immobilization and treatment of uranium in groundwater using a tripolyphosphate (TPP) amendment were completed for the Site: the TPP Pilot Study and the Expanded TPP Pilot Test (HMC 2014 and HMC 2016). TPP treatment employs the injection solution containing TPP and other amendments to promote uranyl phosphate precipitation, which immobilizes dissolved uranium.

The TPP Pilot Study included evaluation of two areas of the alluvial aquifer within the hydraulic barrier established by Homestake as part of the Site groundwater remediation program:

- West of the LTP, referred to as the S Area, where the alluvial aquifer exhibited relatively high hydraulic conductivity and high influx of uranium
- Northeast of the LTP, referred to as the X Area, where the alluvial aquifer exhibited relatively low hydraulic conductivity and lower influx of uranium

The performance monitoring data collected from the S Area demonstrated effective treatment of uranium. Key observations from the TPP Pilot Study monitoring in the S Area are as follows:

- Up to 97 percent of the uranium was removed from the dissolved phase in the S Area. Six wells exhibited uranium treatment greater than 90 percent during the course of the TPP Pilot Study. Nine wells exhibited dissolved uranium concentrations below the Site standard of 0.16 milligrams per liter (mg/L). Baseline concentrations at these locations ranged from 0.17 mg/L to 1.9 mg/L.
- Uranium treatment remained high after the injection solution had washed out as indicated by tracer, TDS, and chloride concentrations. Similarly, uranium concentrations have

steadily decreased in some wells, as the normalized concentration of key amendment signature parameters has remained low.

- Uranium treatment persisted as the fluorescent tracers, TDS, and chloride washout from the radius of influence (ROI). This indicates that dissolved uranium is being transported into the treatment zone from upgradient areas and being immobilized by the phosphate precipitates.

In the X Area, the distribution of the injection solution (approximately 8 feet around the injection well) was smaller than was observed in the S Area, likely the result of lower groundwater velocities and finer-grained material in the X Area. Key observations are summarized below:

- Peak dissolved uranium treatment in the dose response wells ranged from 35 percent to 58 percent in the X Area. At the injection well, uranium treatment remained at 99 percent through 182 days post injection.

- The data demonstrated that the TPP amendment immobilized uranium in the X Area, but overall treatment efficiency was lower than observed in the S Area.

Push-pull tests and soil coring analysis were conducted to evaluate the long-term stability of the treatment. Results and conclusions from these studies are summarized as follows:

- In the S Area, where a greater degree of phosphate distribution was achieved during the TPP Pilot Study, uranium and phosphate concentrations remained below pre-push pull baseline levels and significantly below pre-TPP Pilot Study concentrations.

- In the X Area, uranium concentrations increased above pre-push pull baseline levels. However, this increase is likely due to mixing with untreated groundwater rather than liberation of precipitated uranium, given the lower degree of reagent distribution achieved in the X Area during the TPP Pilot Study. This observation is consistent with observed phosphate concentrations (which remained below baseline levels during the push pull test), as well as uranium concentrations observed in the X Area dose response wells (which were approximately an order of magnitude above uranium concentrations observed during the pull phase).

- The results of the soil coring showed that the TPP injections did not alter the bulk geochemical environment of the aquifer within the S Area and X Area. This finding indicates that a profound change in the geochemical nature of the aquifer is not likely result from TPP injections.

- Uranium, calcium, and phosphate are not easily liberated from soil by extraction with groundwater. Strong acid was required to liberate the majority of calcium and phosphorus from the soil. The evaluation indicated that the precipitation footprint for uranium in the aquifer is diffuse (without significant concentration of uranium in any one area of the treatment zone) and at the full-scale, the concentration of uranium in soil will likely only be slightly higher than currently present in background locations.

In 2015, the Expanded TPP Pilot Test was conducted to implement this technology at a larger scale. The alluvial aquifer near the southwest corner of the LTP was selected as the area for the large-scale TPP application because of both its proximity to the LTP and the presence of a high mass flux corridor of dissolved uranium in alluvial groundwater. Major elements of the expanded pilot test included:

- 34 injection wells, 7 extraction wells, and 16 performance monitoring wells
- Injection of 1.19 million gallons of TPP injectate over a six week period
- Groundwater monitoring for nine months post-injection.

The Expanded TPP Pilot Test reported similar success in treating uranium:

- Up to 93% of uranium was removed from the dissolved phase at the point of injection.
- Nine wells near the expanded TPP transect exhibited significant uranium treatment during the course of the pilot test (up to 86% treatment) and treatment ranged from 84% to 45% at seven wells.
- Uranium treatment remained strong after the injection solution had washed out.

The following is a summary of the evaluation of the results of the TPP Pilot Studies:

- Effectiveness: The TPP Pilot Studies demonstrated rapid in-situ treatment of dissolved uranium. Uranium treatment persisted even as the tracers and reagents washed out from the ROI. Sustained treatment without rebound in uranium concentrations suggests that dissolved uranium flowing into the treatment zone is immobilized by phosphate precipitates. In addition, push-pull testing indicated that precipitated uranium was not likely to re-mobilize. However, the results from the X Area indicate that in areas of the aquifer with lower permeability, reagent distribution is limited, and thus the technology is less effective in these areas. The pilot studies demonstrate that TPP injection is not effective in treating other site contaminants, such as selenium and molybdenum. In addition, concentrations of chloride and TDS increased after injection, but did not persist.

- Implementability: The TPP Pilot Studies suggests that in-situ TPP treatment can be implemented without significant alteration to the aquifer geochemistry or long-lasting secondary water quality effects. Implementation requires the installation of injection and monitoring wells specifically designed for the technology. Based on the ability to treat relatively high concentrations of uranium, this technology is best implemented at key locations within the aquifer to focus treatment on areas where uranium concentrations in groundwater are elevated and persistent. Additional pilot scale TPP injection systems are permitted by the State of New Mexico authorized discharge permit currently held for the Site. Implementation of full-scale TPP treatment system may require revision to the discharge permit.

- Cost: Detailed cost estimates have not been compiled to evaluate full scale implementation of TPP treatment. Generally low hydraulic conductivities in large parts of the tailing increases the number of wells needed for large scale implementation, resulting in a moderate to high relative cost.

3.2 Electrocoagulation Treatment

A pilot study for ex-situ treatment of extracted groundwater using electrocoagulation (EC) treatment technology was completed for the Site (CleanWave 2013). Electrocoagulation introduces an electrical current in the feed water that destabilizes suspended particles, multivalent metals, and organic compounds. For this Site, destabilizing and removing the metals was the objective. Once destabilized, positively charged ions react with negatively charged particles in the water column resulting in stable particles that drop out of solution. Iron and dibasic sodium phosphate are used as flocculants. For the Electrocoagulation Pilot Study, a 100 gpm water treatment system was constructed south of the existing RO WTP. Multiple treatment steps were included in the process including (in sequence) aeration, EC, pH adjustment, solid separation tanks, silica media filter, ultra-filtration filter, and ion-exchange resin. The goal of the pilot study was to remove uranium and other chemical components from extracted groundwater and to estimate the operational parameters for a full-scale water treatment system. Prior to the pilot study, 30 gallons of water from the Site were treated with EC-based technology at a laboratory scale.

On September 16, 2013, the EC pilot study began with 5 days to set-up followed by four weeks of operation, five days per week. A total of 965,000 gallons of water were treated.

Table 3-1 summarizes the results of the EC pilot study.

Table 3-1 Summary of Electrocoagulation Pilot Study

Parameter	Project Influent Average (mg/l)	Project Effluent Average (mg/l)	Alluvial Aquifer Site Standard (mg/l)	Effluent Compliance
Uranium	3.02	0.026	0.16	YES
Molybdenum	2.2	0.864	0.1	NO
Selenium	0.14	0.172	0.32	YES
Sulfate	978	1,008	1,500	YES
Chloride	198	515	250	NO
TDS	2,279	2,647	2,734	YES

The following is a summary of the evaluation of the results of the Zeolite Pilot Study:

- Effectiveness: The EC technology was effective in removing uranium; however, the system configured for the pilot study was unable to reduce molybdenum concentrations to below the Site standard. Operators of the EC treatment system recommended separate removal steps after the EC process to remove uranium and molybdenum. Chloride concentrations increased during the treatment to above the Site standard, due to the chloride-based resin used in the ion-exchange unit.

- Implementability: An EC treatment system would use a proprietary EC unit coupled with standard treatment equipment, which could be implemented at the Site. However, the pilot study did not meet its stated goal of removing all Site contaminants to below Site Standards. Additional studies would be required to determine whether the EC technology could be implemented to produce effluent that meets Site standards. Implementation of a full-scale EC treatment system is permitted by the existing State of New Mexico discharge permit currently held for the Site.

- Cost: The estimated cost for full-scale implementation of an EC treatment system is estimated to be $9M. Annual operating costs are estimated to be $675,000 per year.

3.3 In-Situ Biological Treatment

Over a two year period, 2009-2010, pilot testing was conducted at two locations near the LTP to evaluate the effectiveness of anaerobic in-situ biological treatment. Specifically, the testing targeted the reduction of dissolved uranium, selenium, molybdenum, sulfate, and nitrate in the alluvial aquifer by injecting nutrients into the aquifer to stimulate robust growth of specific organisms. Column tests completed in 2001-2002 were used to develop optimal carbon, nitrate, and phosphorus ratios in the injectate (EDE 2010).

The two location selected, referred to as the East Site and the West Site, were chosen to represent area at the site with low and high hydraulic conductivity, respectively. At the East Site, there were two injection wells, two pumping wells and four wells used for monitoring. At the West Site, one injection wells was used, along with two pumping wells and seven wells used for monitoring. Injections started in May 2009 and monitoring continued into 2010.

Results of the biological stimulation were variable. At the East Site, where hydraulic conductivity is relatively low, results were mostly positive, with consistently lower concentrations of uranium, selenium, and molybdenum reported. Effect on sulfate and nitrate concentrations were mostly neutral. In the West Site, where the aquifer formation is mostly sand and has a much higher hydraulic conductivity, results were neutral to poor. Particularly poor results were recorded for selenium concentrations which rose in more than one well. Generally, poor results on the West Side were attributed to relatively high rates of groundwater movement and some mechanical problems that arose during the study, resulting in inconsistent injection.

- Effectiveness: As described above, reduction in the concentrations of uranium, molybdenum, and selenium, particularly on the East Site, demonstrate potential for the effective treatment. However, the objective of the pilot testing was to permanently meet site specific water quality standards and the objective was not met.

- Implementability: Additional studies would be required to refine the application of this technology and produce effluent that meets Site standards. Implementation of a full-scale biological stimulation system would likely require modification of the existing State of New Mexico discharge permit and NRC license SUA-1471 currently held for the Site.

- Cost: Detailed cost estimates have not been compiled to evaluate full scale implementation of in-situ biological treatment. Similar to TPP chemical treatment, full scale implementation would require a large number of wells as well as equipment and materials to deliver the injectate into the aquifer. Based on these factors, cost would be relatively moderate to high.

SECTION 4 GENERAL RESPONSE ACTIONS

Identification of general response actions is the first step in the remedial alternatives review process. The general response actions are general categories of remedial technologies. For each general response action, several possible remedial technologies may exist. Remedial technologies can be further broken down into a number of process options. Section 4.0 of this memorandum identifies remedial technologies and process options for each of the general response actions. Remediation at this site has been on-going since the 1970's, and many remedies have been implemented at the Site. This section will note remedies that are currently being implemented at the Site or that were completed.

Investigations of Site groundwater (OU1) in the alluvial, upper, middle, and Chinle aquifers indicate impact from historical milling operation. The source of groundwater contamination is the tailing piles and the pore water that exists within the tailings.

While some source control general response actions are applicable to the restoration of groundwater quality (RAO1), groundwater contamination extends beyond the footprint of the tailings piles, thus source control alone will not meet this objective. General response actions which restore groundwater quality that may be applicable to OU1 include:

- Institutional Controls (ICs) –ICs may provide protection from exposure by limiting uses of the Site to activities that do not allow access to Site contaminants. As this is a mature site, several institutional controls have already been implemented, including:
    - Deed Restrictions - Deeds for HMC property in the area of influence include restrictions on domestic wells
    - City Water Supply – HMC has funded the extension of existing municipal water system to serve residents in the area of influence. All residents in the subdivisions are supplied domestic water from the City of Milan except one.
    - Groundwater Monitoring – HMC has been monitoring groundwater for more than four decades.

  Although these ICs are implemented, they will be carried forward through the screening and included in the alternatives development, screening, and detailed analysis.
- Engineering Controls – Engineering controls may be used as a type of containment or physical measures that prevent or minimize exposure to hazardous substances or reduce the mobility or migration of hazardous substances. At this site, hydraulic containment is an engineering control that has been implemented to capture ground water impacted from

tailings seepage for collection via extraction wells.

- Source Control – Source control measures seek to reduce or remove the source of the COCs that are impacting groundwater quality. Source controls that have been implemented at the site include tailing flushing, which was implemented from the late 1990's until 2015 to flush contaminates from the vadose zone and alluvial aquifer.

- Treatment– Treatment can consist of a wide number of technologies including those that involve physical, chemical, or biological treatment of contaminants in place (in-situ) and those that involve collection of contaminated media, treatment above ground, and discharge or disposal of the treated material (ex-situ). Methods of collection and discharge are screened separately from treatment alternatives and are included in the assembly of alternatives following screening.

Monitoring data also suggest that radon in air, although only slightly above background and within codified Federal limits, presents a risk to future on-site workers. Tailings are the primarily source of Site-related radon emissions. General response action(s) that focus on source control measures to reduce or eliminate exposure to the tailings that may be applicable for OU2 include:

- Institutional Controls – ICs may provide protection from exposure by limiting uses of the Site to activities that do not allow access to site contaminants. Several ICs applicable to this RAO have already been implemented, including:

  - Radon emissions from the Site and background are routinely measured to identify exposures and data trends.

  - Fencing has been erected at the Site to limit access

  - Federal regulation require DOE to own and operate the Site after remediation is complete, which will limit public access to the site in perpetuity.

  Similar to the implemented ICs applicable to groundwater restoration, these will be carried forward through the screening and included in the alternatives development, screening, and detailed analysis.

- Engineering Controls – Engineering controls may be used as a type of containment or physical measures that prevent or minimize exposure to hazardous substances or reduce the mobility or migration of hazardous substances. Radon barrier is an engineering control that has been place on the side slopes and the top of the LTP and STP. In addition, access to the mill tailing area is controlled by fencing and security surveillance.

- Source Control – Source control measures seek to reduce or remove the source of the

COCs. Source controls that have been implemented at the site include demolition of surface facilities which supported uranium milling and remediation of soils round the facility was completed in 1995. These source materials were buried on-site and encased in grout.

- Treatment – Treatment can consist of a wide number of technologies including those that involve physical, chemical, or biological treatment of contaminants in place (in-situ) and those that involve removal of contaminated media, treatment above ground, and discharge or disposal of the treated material (ex-situ).
- Removal and Disposal – The removal/disposal option consists of physically removing the contaminated media from the Site and disposing at a licensed off-site facility.

Typically, remedies selected include components of several general response actions, especially when remedial action objectives include more than one media. In this case, there are two media of concern: groundwater and air.

In addition to the general response actions listed above, a No Action alternative is retained throughout this feasibility study process as a baseline for comparison, as required under 40 CFR 300.430(3)(6).

SECTION 5 IDENTIFICATION AND SCREENING OF REMEDIAL TECHNOLOGIES AND PROCESS OPTIONS

This section identifies remedial technologies for each of the general response actions identified in Section 2 and selects process options that represent these remedial technologies. Process options are initially screened based on technical feasibility and then a more detailed screening is completed evaluating and screening each option based on effectiveness, implementability and cost.

5.1 Initial Screening

Remedial technologies are general categories of technologies, such as chemical treatment, thermal destruction, immobilization, capping, dewatering, etc. Several broad remedial technologies have been identified for each general response action. Numerous process options may exist within each remedial technology type. For example, chemical treatment is a remedial technology and process options for this technology include precipitation, ion exchange, and adsorption.

When identifying remedial technologies for radioactive material it is important to understand that the characteristics of radioactive material constrain the available technologies. Unlike many chemicals, radioactive materials cannot be altered by physical, chemical, or biological processes. Since destruction of radioactivity is not an option, response actions at radioactively contaminated sites must rely on measures that prevent or reduce exposure to radiation. Remedial technologies and process options identified to address groundwater and radon emission that address radioactivity include those technologies that prevent and reduce exposure. Others, such as thermal destruction and biological processes, are not considered.

The RAOs identify two media that require remediation: groundwater (RAO1) and air (RAO2). Although each share the same source (uranium tailings), general response action, technologies and process options for each will be screened and evaluated for each. It is recognized that some remedial alternatives may impact to both media. For instance, removal and off-site disposal of tailings will impact groundwater remediation. When assembling alternatives, overlapping impacts will be evaluated and considered.

During the initial screening step in a CERCLA FS, process options and entire remedial technology types are eliminated from further consideration on the basis of technically implementability. Examples of non-implementability include difficult to implement due to site constraints and the technology has not been proven to effectively control the contaminant of concern. This initial screening step is applied based on published information and experience with the technologies and process options, knowledge of the site characteristics, and engineering judgment.

Table 5.1 identifies general response actions, candidate remedial technologies, and process options for groundwater (RAO1, OU1). Table 5.2 lists general response actions, candidate remedial technologies, and process options to reduce radon emissions (RAO2, OU2). Screening comments in these tables provided the basis for eliminating options.

Table 5-1 Initial Screening of Candidate Remedial Technologies and Process Options for Groundwater Restoration

General Response Action	Remedial Technology	Process Option	Description	Applicability
No Action	None	Not Applicable	No action	Required as baseline for comparison purposes
Institutional Controls	Access Restrictions	Deed Restrictions	Deeds for HMC property in the area of influence include restrictions on wells	Potentially Applicable
		Local Government Ordinance	Ordinances would be enacted to make it unlawful to use wells within the area of influence to use wells for domestic purposes	Potentially Applicable
	Alternate Water Supply	City Water Supply	Extension of existing municipal water system to serve residents in the area of influence	Potentially Applicable
	Monitoring	Groundwater Monitoring	Ongoing monitoring of wells	Potentially Applicable
Engineering Controls	Containment	Hydraulic Barrier	Use of water extraction and injection to create hydraulic mounds of water to contain contaminants and create capture zones	Potentially Applicable
		Slurry Wall	Consist of a vertically excavated trench filled with low permeability slurry	Not applicable due to presence of multiple sub cropping aquifers and required depths of greater than 100 feet bgs
		Grout Curtain	Constructed by pressure-injecting grout directly into the soil at closely spaced intervals	Not applicable due to presence of multiple sub cropping aquifers and required depths of greater than 100 feet bgs
		Sheet Piling	Constructed by driving interlocking steel or high-density polyethylene into the ground and sealing between individual sheets	Not applicable due to presence of multiple sub cropping aquifers and required depths of greater than 100 feet bgs

Table 5-1 Initial Screening of Candidate Remedial Technologies and Process Options for Groundwater Restoration (Con't)

General Response Action	Remedial Technology	Process Option	Description	Applicability
Engineering Controls	Injection	Tailings Flushing	Fresh water injection into tailings to accelerate draindown and drive pore water in the vadose zone into capture zones of recovery wells.	Potentially Applicable
	Capping	Impermeable Cap	Installation of impermeable caps on the tailings to prevent infiltration from driving vadose zone pore water into the alluvial aquifer	Potentially Applicable
In-Situ Treatment	Chemical Treatment Chemical Treatment	Chemical Precipitation	The technology involved the addition of amendments to induce precipitation, which immobilizes COCs	Potentially Applicable
		Permeable Reactive Barriers	Permeable reactive barriers are installed in the subsurface across the flow path of a radionuclide-contaminated groundwater plume, treating the groundwater while it flows through the wall. Treatment is accomplished by employing various treatment agents.	Not applicable due to presence of multiple sub cropping aquifers and required depths of greater than 100 feet bgs. In addition, due to the relatively flat hydraulic gradient and with the size of the plume, remediation using passive barrier walls would likely take several decades.
	Natural Attenuation	Monitored Natural Attenuation	Natural attenuation occurs in the subsurface at most radioactively contaminated sites and includes such processes as dispersion, diffusion, sorption, precipitation, and radioactive decay. Monitoring of these processes to confirm that natural attenuation is taking place is termed monitored natural attenuation.	Due to the high concentration of COCs, monitored natural attenuation is not practicable for this Site.
	Biological	Phytoextraction	The uptake of contaminants by plant roots and the translocation/ accumulation of contaminants into plant shoots and leaves. Plants are subsequently harvested from the growing area, dried, and disposed.	Not Applicable – The depth to groundwater and thickness of the alluvial aquifer makes this impracticable

Table 5-1 Initial Screening of Candidate Remedial Technologies and Process Options for Groundwater Restoration (Con't)

General Response Action	Remedial Technology	Process Option	Description	Applicability
In-Situ Treatment	Biological	Bio stimulation	Injection of a substrate to create anaerobic conditions. The anaerobic conditions reduce the oxidation states of uranium, molybdenum, and selenium, which are removed from groundwater through creation of low solubility metal/nonmetal precipitates.	Potentially Applicable
Ex-Situ Treatment	Chemical Treatment	Ion Exchange	Chemical process that separates and replaces radionuclides in a waste stream with relatively harmless ions from a synthetic resin or natural zeolite	Potentially Applicable
		Adsorption	Dissolved contaminants in the groundwater are adsorbed by sticking to the surface and within the pores of selected media.	Potentially Applicable
	Physical Treatment	Membrane Filtration	Uses a selectively permeable membrane that allows water to pass through it, but which traps radionuclide ions on the concentrated, contaminated liquid side of the membrane	Potentially Applicable

Table 5-1 Initial Screening of Candidate Remedial Technologies and Process Options for Groundwater Restoration (Con't)

General Response Action	Remedial Technology	Process Option	Description	Applicability
Collection	Wells	Extraction Wells	Use of extraction wells to extract contaminated groundwater	Potentially Applicable
	Trenches	Interceptor Trenches	Use of interceptor trenches to collect contaminated groundwater	Not applicable due to multiple aquifers and thickness of aquifers
Discharge	On-Site Discharge	Evaporation	On-site disposal of water using evaporation ponds	Potentially Applicable
		Deep Well Injection	On-site disposal of treated water using a deep injection well	Deep aquifer is used as regional source of drinking water, so wells would need to be extremely deep, monitoring would be required, and permitting public acceptance is unlikely
	Off-Site Discharge	Local POTW	Discharge of treated water at local POTW	Nearest POTW has insufficient capacity and is a substantial distance from Site (6 miles)
		Nearby Stream or River	Discharge of treated water at nearby stream	Closest significant waterway (Rio San Jose) is more than 5 miles from Site

Table 5-2 Initial Screening of Candidate Remedial Technologies and Process Options for Tailings

General Response Action	Remedial Technology	Process Option	Description	Applicability
No Action	None	Not Applicable	No action	Required as baseline for comparison purposes
Institutional Controls	Monitoring	Radon Emission Monitoring	Radon emissions from the Site and background are routinely measured to identify exposures and data trends	Potentially Applicable
	Access Restrictions	Physical Barriers	Fencing to prevent access to Site	Potentially Applicable
		Deed Restriction	Federal regulation require DOE to own and operate the Site after remediation is complete	Potentially Applicable
		Permanent Relocation of Residents	Permanent relocation of residents in accordance with the Uniform Relocation Act	Potentially Applicable
Engineering Controls	Containment	Capping	Cap to provide suitable radon and dermal barrier for LTP, STP, and evaporation ponds and to provide erosion protection	Potentially Applicable
		Vertical Barrier (Slurry Walls, Grout Curtains, Cryogenic Barriers)	Vertical barriers are installed around a contaminated zone to help confine radioactive waste	Not Applicable – Since the source material is deposited above grade, these containment technologies do not apply.

Table 5-2 Initial Screening of Candidate Remedial Technologies and Process Options for Tailings (Con't)

General Response Action	Remedial Technology	Process Option	Description	Applicability
In-Situ Treatment	Physical	Cement Solidification/ Stabilization	Cement solidification/ stabilization processes involve the addition of cement or a cement-based mixture that limits the solubility or mobility of the waste constituents. In-situ techniques use auger/caisson systems and injector head systems to apply agents to in-situ soils.	Potentially Applicable
	Chemical	Chemical Solidification/ Stabilization	Similar to cement solidification/ stabilization processes except chemical agents such as thermoplastic polymers, thermosetting polymers or other proprietary additives into contaminated materials	Potentially Applicable
	Biological	Phytoextraction	The uptake of contaminants by plant roots and the translocation/ accumulation of contaminants into plant shoots and leaves. Plants are subsequently harvested from the growing area, dried, and disposed	Not Applicable – The thickness of the tailings pile makes this impracticable
	Thermal	Vitrification	Vitrification involves heating contaminated media to extremely high temperatures, then cooling them to form a solid mass.	Not Applicable – The thickness of the tailings pile and the side slopes makes this impracticable

Table 5-2 Initial Screening of Candidate Remedial Technologies and Process Options for Tailings (Con't)

General Response Action	Remedial Technology	Process Option	Description	Applicability
Ex-Situ Treatment	Physical	Cement Solidification/ Stabilization	Cement solidification/ stabilization processes involve the addition of cement or a cement-based mixture that limits the solubility or mobility of the waste constituents. In-situ techniques use auger/caisson systems and injector head systems to apply agents to in-situ soils.	Not Applicable – Ex-situ solutions are not a practical alternative due to the vast quantity of tailings (estimated to be over 22 million tons).
		Vitrification	Vitrification involves heating contaminated media to extremely high temperatures, then cooling them to form a solid mass.	Not Applicable – Ex-situ solutions are not a practical alternative due to the vast quantity of tailings (estimated to be over 22 million tons).
		Separation	Physical separation technologies work on the principle that radionuclides are associated with particular fractions of the media, which can be separated based on particle size. Wet or dry methods have been used.	Not Applicable – Ex-situ solutions are not a practical alternative due to the vast quantity of tailings (estimated to be over 22 million tons).
	Chemical	Chemical Solidification/ Stabilization	Similar to cement solidification/ stabilization processes except chemical agents rather than cement are mixed with contaminated materials.	Not Applicable – Ex-situ solutions are not a practical alternative due to the vast quantity of tailings (estimated to be over 22 million tons).
		Chemical Extraction/ Flotation	Chemical extraction and flotation processes use chemicals to separate radionuclides from soils, sludges, and sediments to reduce the volume of contaminated tailings.	Not Applicable – Ex-situ solutions are not a practical alternative due to the vast quantity of tailings (estimated to be over 22 million tons).
Removal and Disposal	Removal and Disposal	Removal and Disposal	Removal and disposal involves building a cell for permanent disposal of the tailings and other radioactive waste. The cell would be lined and capped. This option could include use of a commercial facility; however, due to the volume of material, commercial disposal is unlikely.	Potentially Applicable

5.2 Detailed Screening of Retained Technologies and Process Options

The potentially applicable remedial technologies and process options carried forward from the initial screening were to reduce the options to evaluate in detail as remedial options. Typically, a single option for each technology is retained; however, due to the scale and complexity of groundwater impacts, multiple options may be retained for use. Effectiveness, implementability, and relative cost of remedial technologies and process options were considered during this screening evaluation.

Effectiveness for each option was screened independently and focused on the following primary considerations:

- Ability to handle the estimated areas or volumes of contaminated media and to meet remedial action objectives
- Potential impacts to human health and the environment during construction
- Reliability and proven performance with respect to site conditions and contaminants

Implementability for each option was screened independently and included consideration of the technical and administrative feasibility. Since the technical implementability was a criterion used in the selection of potentially applicable technologies, it was less a factor at this stage than administrative feasibility. The following factors were considered as part of the implementability evaluation:

- The ability to obtain necessary permits
- The availability and capacity of treatment, storage, and disposal facilities
- The availability of equipment and skilled workers needed to implement the process option

The cost evaluation was limited to a qualitative cost comparison that considers the capital and operation and maintenance (O&M) costs of a particular process option. Costs were characterized as low, moderate, or high based on experience and engineering judgment.

Table 5.3 Detailed Screening of Technologies and Process Options for Groundwater

Response Action	Technology	Process Option	Effectiveness	Implementability	Relative Cost	Retain
No Action	None	None	Does not address RAOs	No action required	No capital No O&M.	Yes
Institutional Controls	Access Restrictions	Deed Restrictions (Site)	Effective	HMC has implemented this institutional control	Low Capital No O&M	Yes
		Local Government Ordinance	Effective	Difficult to implement because of local opposition.	Low Capital No O&M	No
	Alternate Water Supply	City Water Supply	Effective	This has been implemented for all current residences	Low Capital No O&M	Yes
	Monitoring	Groundwater Monitoring	Effective	HMC is currently monitoring groundwater	Low Capital Low O&M	Yes
Engineering Controls	Containment	Hydraulic Barrier	Hydraulic barriers have been moderately effective; however, they have not prevented all downgradient migration of COCs.	This option has been implemented at the Site.	Low Capital Mid O&M	Yes
	Injection	Tailings Flushing	Tailings flushing was effective in enhancing draindown of contaminated pore water; however effectiveness is limited by the heterogeneity of the tailing pile particle size and continued flushing was discontinued in 2015.	This option was historically implemented at the Site but is no longer effective.	Low Capital Mid O&M	No
	Capping	Impermeable Cap	An impermeable cap would be effective in limiting infiltration. Due to the arid climate, infiltration at this site is relatively low. Venting might be required to control radon gas migration and buildup below the ground surface.	Based on previous investigations, sources of clay suitable for construction of an impermeable cap may not be locally available. Use of geosynthetic materials would be difficult if used in combination with options that require wells due to the high number of penetrations that would be required. Existing erosion protection would need to be removed and replaced. Regrading of side slopes may be required depending on slope stability analysis.	High Capital Mid O&M	No

Table 5.3 Detailed Screening of Technologies and Process Options for Groundwater (Con't)

Response Action	Technology	Process Option	Effectiveness	Implementability	Relative Cost	Retain
In-Situ Treatment	Chemical Treatment	Chemical Precipitation	Pilot studies that have been conducted by HMC using tri-poly phosphate (TPP) as precipitation agent that have showed TPP effective in removing uranium. However, TPP was not effective in removing selenium and molybdenum.	Aquifer heterogeneity and variable groundwater flow make it challenging to distribute injectates and provide consistent retention.	Mid – High Capital Mid O&M	No
	Biological Treatment	Bio stimulation	In the pilot study conducted at the Site, reduction of site contaminants was highly variable. The goal of meeting site standards was not met.	Aquifer heterogeneity and variable groundwater flow make it challenging to distribute injectates and provide consistent retention.	Mid – High Capital Mid O&M	No
Ex-Situ Treatment	Chemical Treatment	Ion Exchange	Ion exchange a common water treatment process where ion-specific resins remove ions from the water. Electrocoagulation pilot study met uranium treatment goals.	Multiple treatment steps were required to meet treatment goals. Separate ion exchange process needed to remove molybdenum.	Mid Capital Mid O&M	Yes
		Adsorption	Adsorption, using zeolite as the media, has been effective in removing uranium at from groundwater and has been implemented at the Site. Zeolite treatment does not have any effect on the concentration of selenium, molybdenum, chloride, nitrate, radium, vanadium, and thorium.	Relatively easy to implement. Use of adsorption using zeolite is currently being used at the Site.	Mid Capital Mid O&M	Yes
	Physical Treatment	Membrane Filtration	Effective in removing radionuclides and a wide range of COCs.	Membrane filtration is currently being used at the Site	Mid Capital Mid O&M	Yes
Collection	Wells	Extraction Wells	Effective	Extraction wells are currently being used at the Site.	Low Capital Low O&M	Yes
Discharge	On-Site Discharge	Evaporation	Effective due to the arid climate	Evaporation ponds are currently being used at the Site.	Mid Capital Low O&M	Yes

Table 5.4 Detailed Screening of Technologies and Process Options for Tailings

Response Action	Technology	Process Option	Effectiveness	Implementability	Relative Cost	Retain
No Action	None	None	Does not address RAOs.	No action required.	No capital No O&M	Yes
Institutional Controls	Monitoring	Radon Emission Monitoring	Effective in measuring the potential human exposure to radon.	HMC is currently monitoring radon emissions	Low capital Low O&M	Yes
	Access Restrictions	Physical Barriers (Site)	Effective, but will not prevent all trespassers from entering the Site	A fence currently encloses the Site	Low capital Low O&M	Yes
		Deed Restriction (Site)	Effective in preventing future exposures	Federal regulations require DOE to take ownership of property in perpetuity	Low capital Low O&M	Yes
		Permanent Relocation of Residents	Permanent relocation of residents id effective in eliminating the residential exposure pathway	Difficult to implement: • requires negotiations with dozens of property owners • requires hundreds of legal transactions • may require use of federal condemnation authority • may be difficult to locate comparable housing • For some, will result in “loss of community” that may complicate community acceptance	High Capitol Low O&M	Yes

Table 5.4 Detailed Screening of Technologies and Process Options for Tailings (Con't)

Response Action	Technology	Process Option	Effectiveness	Implementability	Relative Cost	Retain
Engineering Controls	Containment	Radon barrier	Radon barrier installation is a proven technology to effectively reduce radon emissions and exposure to other COCs.	Easily implemented, but not until groundwater remediation is complete: • Radon barrier has been implemented at the Site in all required areas except the top of the LTP, where an interim cover has been placed. • The final cover for the top of the LTP has been designed and approved by NRC. • Material for the remaining cover has been identified. • Current groundwater remediation efforts require a large number of well on the top of the LTP which preclude installation of the final radon barrier until groundwater remediation is complete.	Medium Capitol Low O&M	Yes

Table 5.4 Detailed Screening of Technologies and Process Options for Tailings (Con't)

Response Action	Technology	Process Option	Effectiveness	Implementability	Relative Cost	Retain
In-Situ Treatment	Physical	Cement Solidification/ Stabilization	The area, volume, and depth of the tailings would limit effectiveness Process creates dust that would need to be controlled Side slopes of LTP would require regrading, resulting in higher releases of radon during implementation Would increase difficulty remediating ground water below the LTP Literature is unclear on effectiveness in reducing radon emissions.	Would require revision to discharge permits and NRC facility license. May be difficult to find the quantity of equipment and materials need to complete solidification/stabilization in a reasonable time frame because of the volume of tailings.	High Capitol Low O&M	No
	Chemical	Chemical Solidification/ Stabilization	The area, volume, and depth of the tailings would limit effectiveness Process creates dust that would need to be controlled Side slopes of LTP would require regrading, resulting in higher releases of radon during implementation Would increase difficulty remediating ground water below the LTP Literature is unclear on effectiveness in reducing radon emissions.	Would require revision to discharge permits and NRC facility license. May be difficult to find the quantity of equipment and materials need to complete solidification/stabilization in a reasonable time frame because of the volume of tailings.	High Capitol Low O&M	No

Table 5.4 Detailed Screening of Technologies and Process Options for Tailings (Con't)

Response Action	Technology	Process Option	Effectiveness	Implementability	Relative Cost	Retain?
Removal and Disposal	Removal and Disposal	Removal and Disposal	Likely effective in reducing radon exposure for nearby residents in the long term; however, exposures from other pathways not reduced. In the short term, would result in higher releases of radon during implementation, which could require several years.	The area, volume, and depth of the tailings make this very difficult to implement. Relocation of 22 million tons would be a massive construction effort, during which physical hazards would cause injuries, dust would be created, and large amounts of fossil fuels would be burned, adding greenhouse gasses to the atmosphere. In addition, transportation of material will create a risk to the public. If removal and disposal is required to an off-site location (as defined by the NCP and related guidance), permitting a new facility would be a substantial hurdle to overcome.	High Capital Low O&M	No

Tables 5-5 and 5-6 summarize the retained remedial technologies and process options carried forward from the detailed screening for remediation of groundwater and the tailings.

Table 5.5 Summary of Detailed Screening of Technologies and Process Options for Groundwater

Response Action	Technology	Process Option
No Action	None	None
Institutional Controls	Access Restrictions	Deed Restrictions (Site)
	Alternate Water Supply	City Water Supply
	Monitoring	Groundwater Monitoring
Engineering Controls	Containment	Hydraulic Barrier
Ex-Situ Treatment	Adsorption	Zeolite
	Chemical Treatment	Ion Exchange
	Physical Treatment	Membrane Filtration
Collection	Wells	Extraction Wells
Discharge	On-Site Discharge	Evaporation

Table 5.6 Summary of Detailed Screening of Technologies and Process Options for Tailings

Response Action	Technology	Process Option
No Action	None	None
Institutional Controls	Monitoring	Radon Emission Monitoring
	Access Restrictions	Physical Barriers (Site)
		Deed Restriction (Site)
		Permanent Relocation of Residents
Engineering Controls	Containment	Radon barrier

SECTION 6 ASSEMBLY OF REMEDIAL ALTERNATIVES

The objective of this section is to combine the list of previously screened technologies and process options to form a range of remedial action alternatives that meet the RAOs. The screening was conducted to eliminate alternatives that achieved the same RAOs but were considered less feasible or costly. Alternatives were developed by assembling combinations of representative process options that survived the screening in Section 5.0. Assembled alternatives range from no further action to alternatives that utilize treatment technologies to reduce the toxicity, mobility, or volume of the contaminants.

Alternatives are divided into three categories addressing:

- Groundwater (Alternatives with an "GW" prefix)
- Tailing (Alternatives with a "T" prefix)
- Institutional Controls (Alternatives with a "IC" prefix)

For groundwater, the ICs carried forward have been implemented, so these have been grouped together and included in each of the alternatives. Experience with the project site has found that collection of contaminated water for ex-situ treatment is aided by use of hydraulic barriers, so this alternative is included in each of the ex-situ alternatives.

Ion exchange and adsorption have been found to effective in treating uranium, but is not effective in reducing the concentration of other contaminants. For this reason, it is not considered as a standalone treatment option and is paired with membrane filtration.

The following is the remedial action alternatives have been developed to address the groundwater RAOs:

1. Alternative GW1 – No Action
2. Alternative GW2 – Institutional Controls, Injection to Create a Hydraulic Barrier, Collection using Extraction Wells, Treatment with Ion Exchange and Membrane Filtration, and Discharge to Evaporation Ponds
3. Alternative GW3 – Institutional Controls, Injection to Create a Hydraulic Barrier, Collection using Extraction Wells, Treatment with Adsorption and Membrane Filtration, and Discharge to Evaporation Ponds

For the tailings, physical barriers, and deed restriction are included for all alternatives. These are collectively referred to as institutional controls.

The following is the remedial action alternatives have been developed to address the tailings RAOs:

1. Alternative T1 – No Action

2. Alternative T2 – Permanent Relocation of Subdivision Residents with Institutional Controls
3. Alternative T3 – Radon Barrier with Institutional Controls

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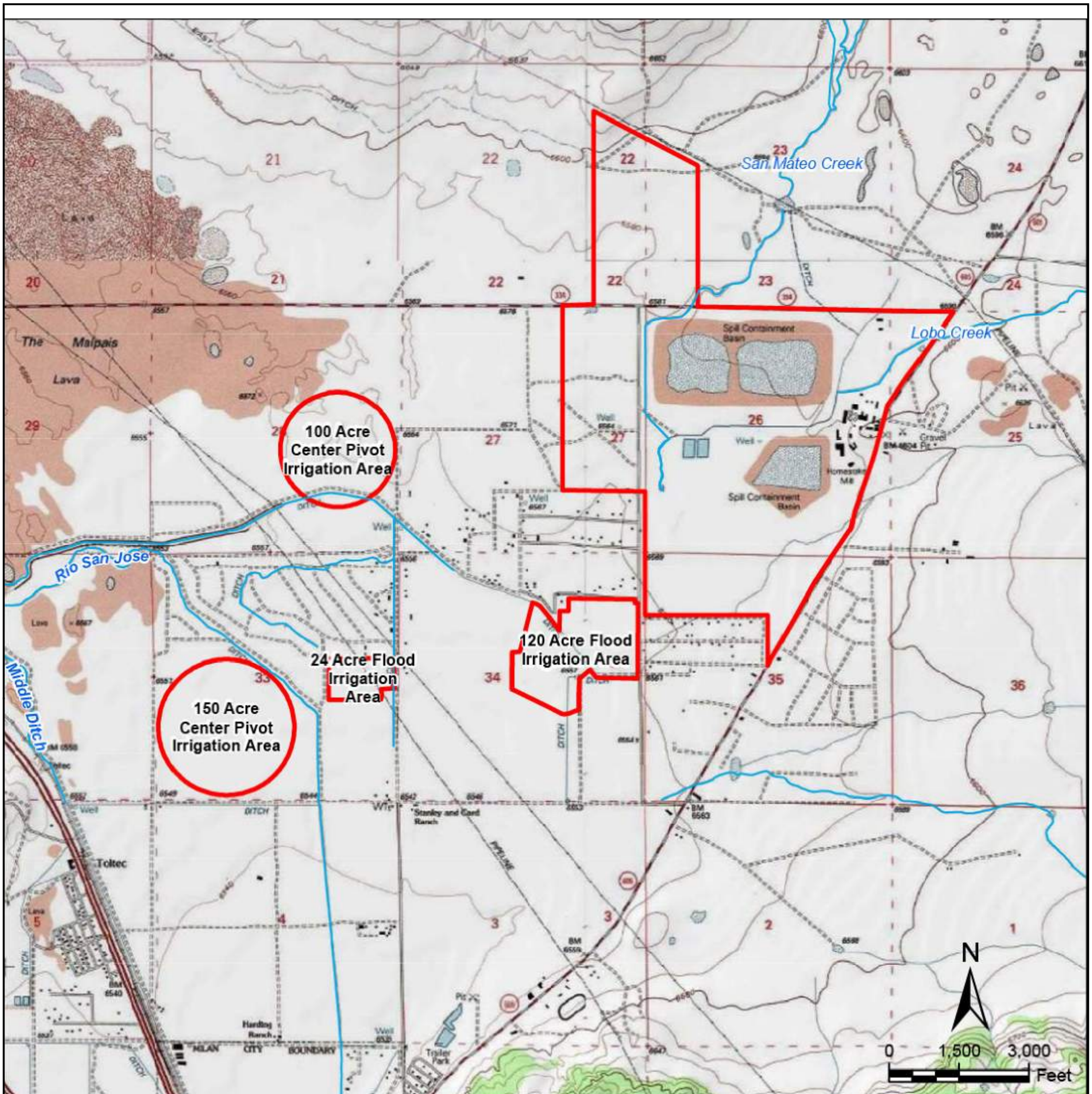
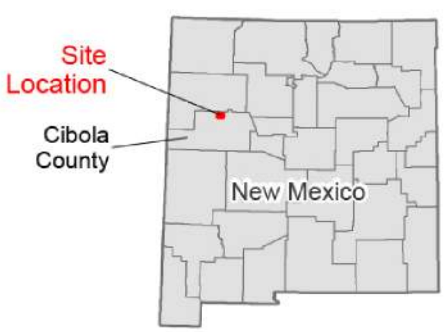
FIGURES



Source: USA Topo Maps: National Geographic Society, i-cubed



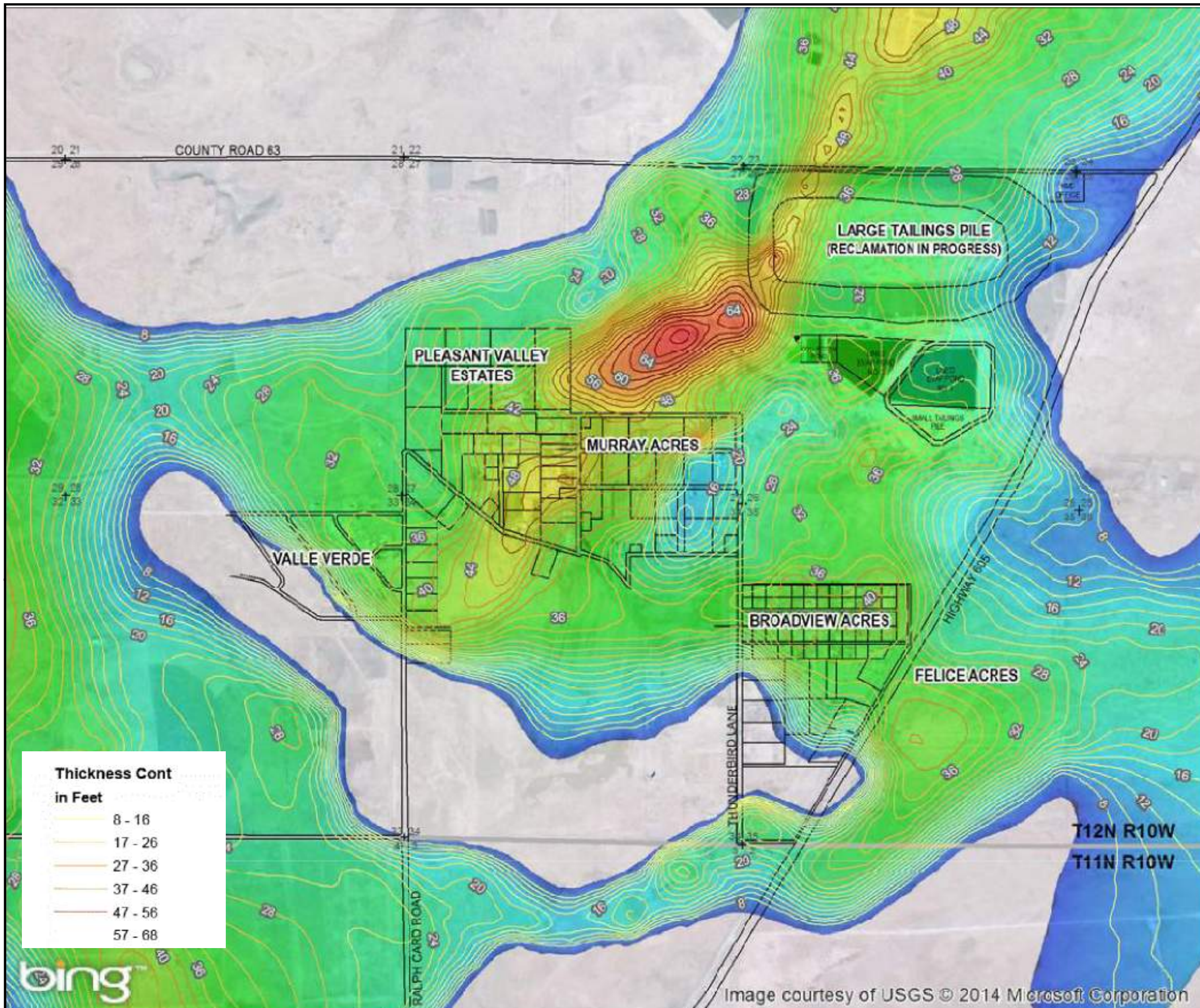
LEGEND:
- Rivers & Streams
- Site Areas

Adopted from: Grants Reclamation Project Updated Corrective Action Program, HMC, 2012

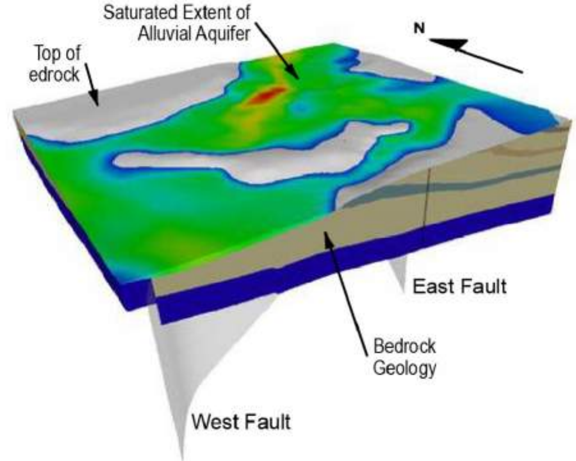
SITE LOCATION MAP

DEVELOPMENT AND SCREENING OF
REMEDIAL ALTERNATIVES TECHNICAL MEMORANDUM

FIGURE 1-1



3D BEDROCK GEOLOGY AND SATURATED EXTENT OF ALLUVIAL AQUIFER - FACING NORTHEAST



LEGENDS:

Saturated Alluvial Thickness (feet)

69
60
52
43
34
26
17
9
0

Bedrock Hydrostratigraphy

- Chinle Shale
- Upper Chinle Aquifer
- Chinle Shale
- Middle Chinle Aquifer
- Chinle Shale
- Lower Chinle Aquifer
- Chinle Shale
- San Andres-Glorietta Aquifer

0 1,350 2,700
Feet

N

Source: Grants Reclamation Project Updated Corrective Action Program, HMC, 2012

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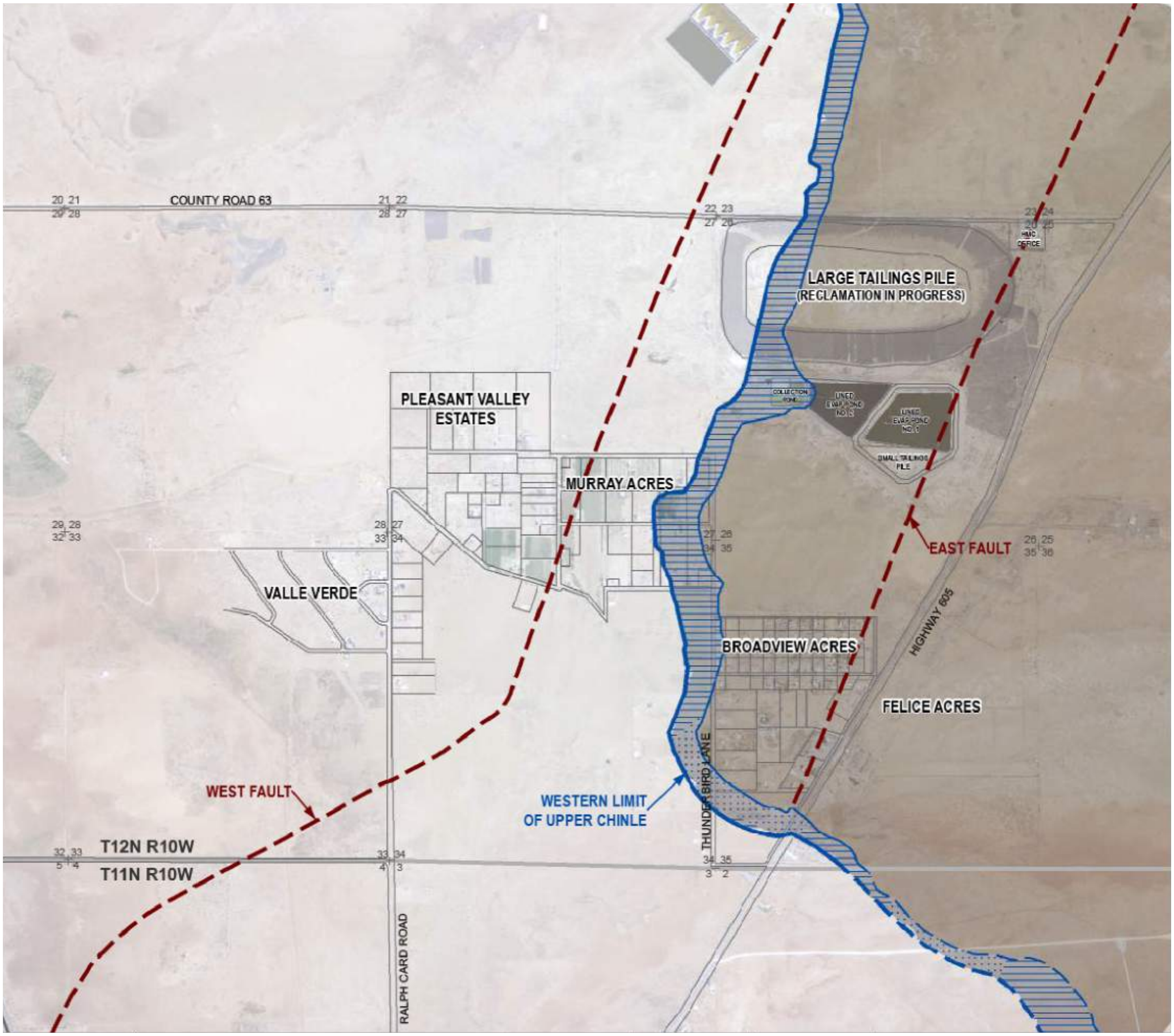
SATURATED EXTENT OF ALLUVIAL AQUIFER
DEVELOPMENT AND SCREENING OF
REMEDIAL ALTERNATIVES TECHNICAL MEMORANDUM
FIGURE 1-2



LEGEND:

Fault

Subcrop of Upper Chinle Alluvium Overlies Sandstone

(Subcrop boundary dashed where inferred)

Saturated Alluvium

Unsaturated Alluvium

Extent of Upper Chinle Aquifer with Elevation Contour (ft-amsl)

N

0 1,250 2,500 Feet

Aerial Source: NAIP 2011
Adopted from: Grants Reclamation Project Updated Corrective Action Program, HMC, 2012

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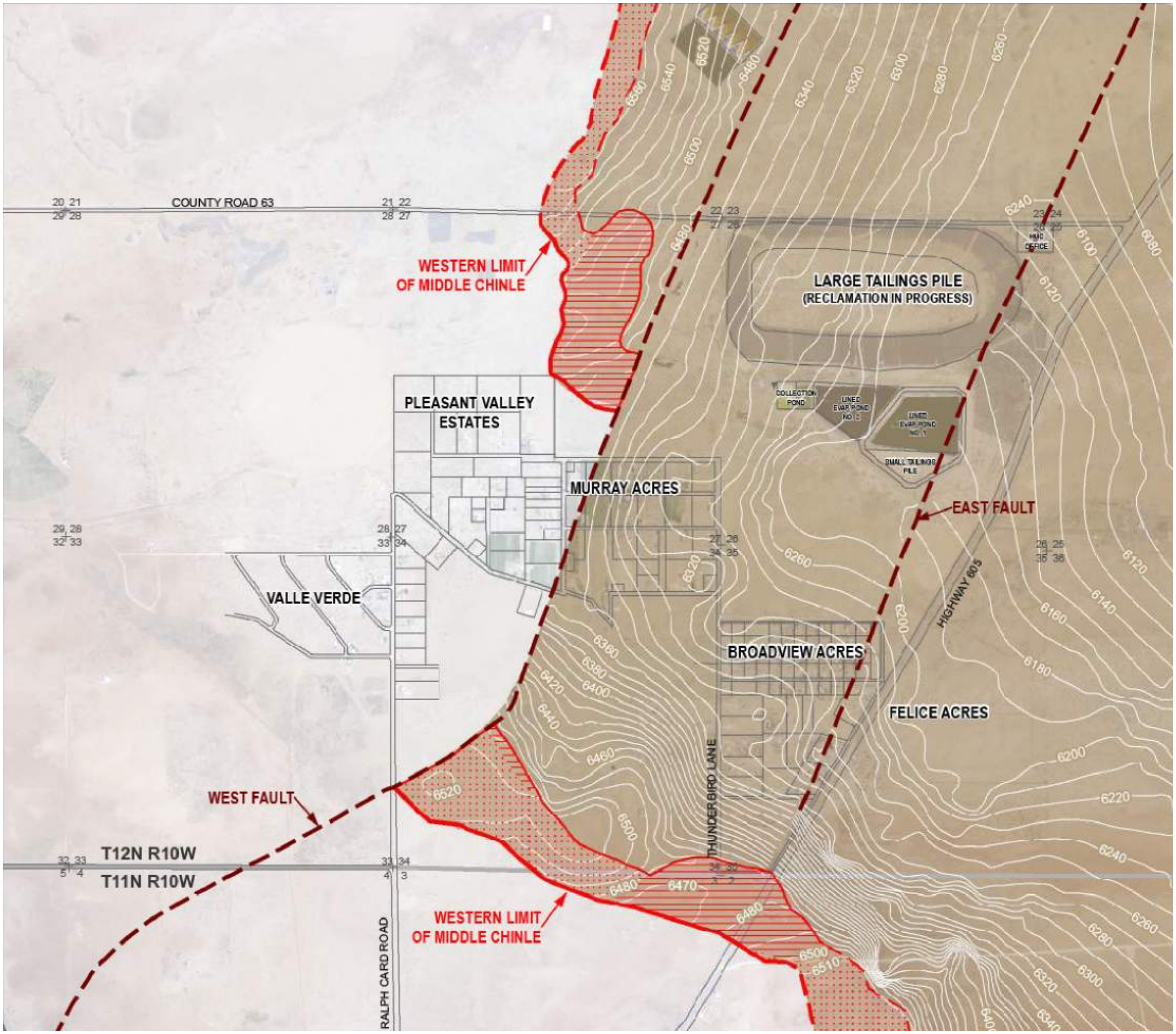
EXTENT OF UPPER CHNLE AQUIFER

DEVELOPMENT AND SCREENING OF REMEDIAL ALTERNATIVES TECHNICAL MEMORANDUM

FIGURE 1-3



LEGEND:

Fault

Subcrop of Middle Chinle Alluvium Overlies Sandstone

(Subcrop boundary dashed where inferred)

Saturated Alluvium

Unsaturated Alluvium

Extent of Middle Chinle Aquifer with Elevation Contour (ft-amsl)

N

0 1,250 2,500 Feet

Aerial Source: NAIP 2011
Adopted from: Grants Reclamation Project Updated Corrective Action Program, HMC, 2012

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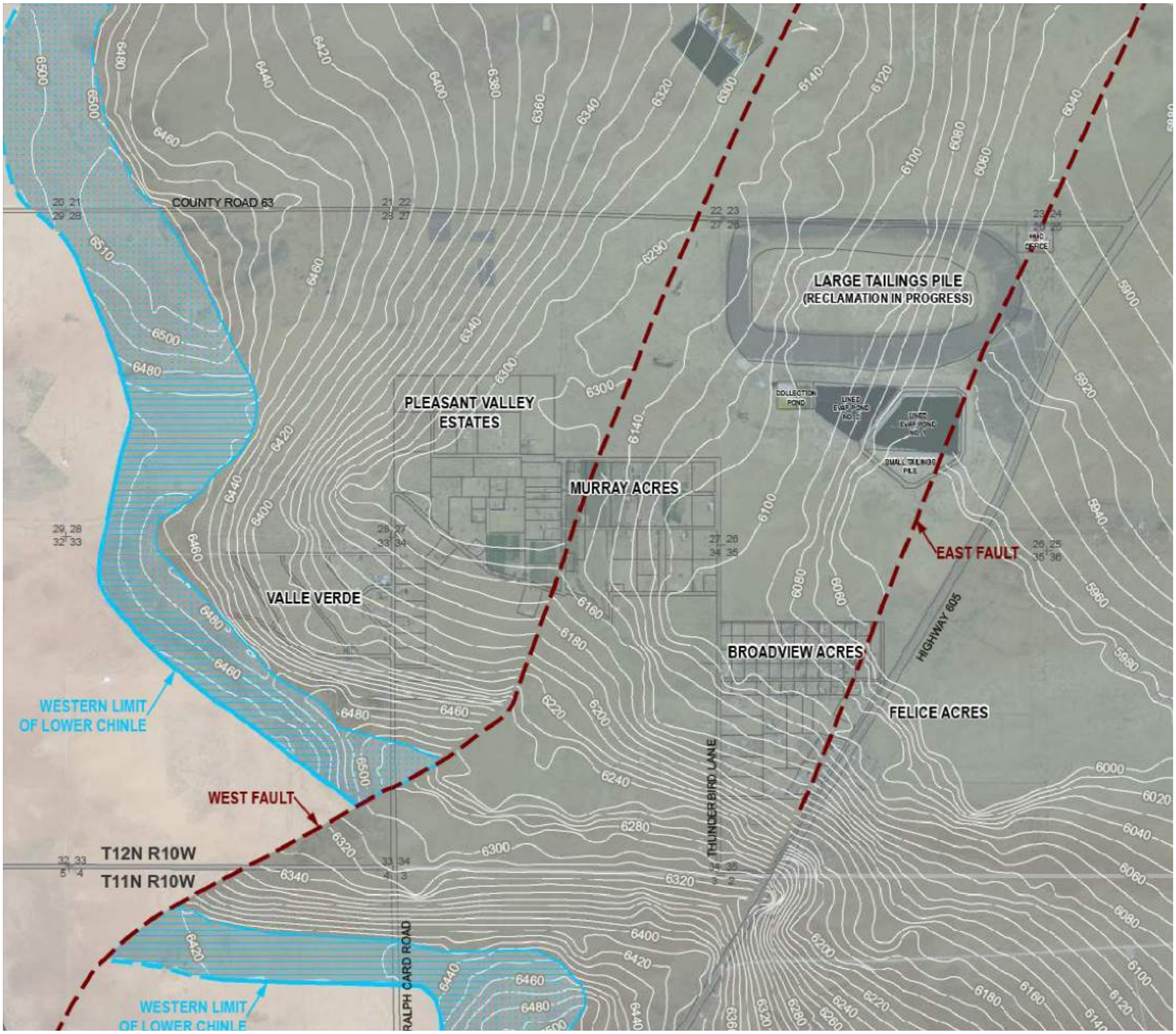
EXTENT OF MIDDLE CHNLE AQUIFER
DEVELOPMENT AND SCREENING OF REMEDIAL ALTERNATIVES TECHNICAL MEMORANDUM
FIGURE 1-4



LEGEND:

Fault

Subcrop of Lower Chinle Alluvium Overlies Secondary Porosity

(Subcrop boundary dashed where inferred)

Saturated Alluvium

Unsaturated Alluvium

Extent of Lower Chinle Aquifer with Elevation Contour (ft-amsl)

N

0 1,250 2,500 Feet

Aerial Source: NAIP 2011
Adopted from: Grants Reclamation Project Updated Corrective Action Program, HMC, 2012

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EXTENT OF MIDDLE CHNLE AQUIFER
DEVELOPMENT AND SCREENING OF REMEDIAL ALTERNATIVES TECHNICAL MEMORANDUM
FIGURE 1-5

LEGEND:

Fault

Subcrop of San Andres-Glorietta Alluvium Overlies Limestone

Saturated Alluvium

Extent of San Andres-Glorietta Aquifer with Elevation Contour (ft-amsl)

N

0 1,250 2,500 Feet

Aerial Source: NAIP 2011
Adopted from: Grants Reclamation Project Updated Corrective Action Program, HMC, 2012

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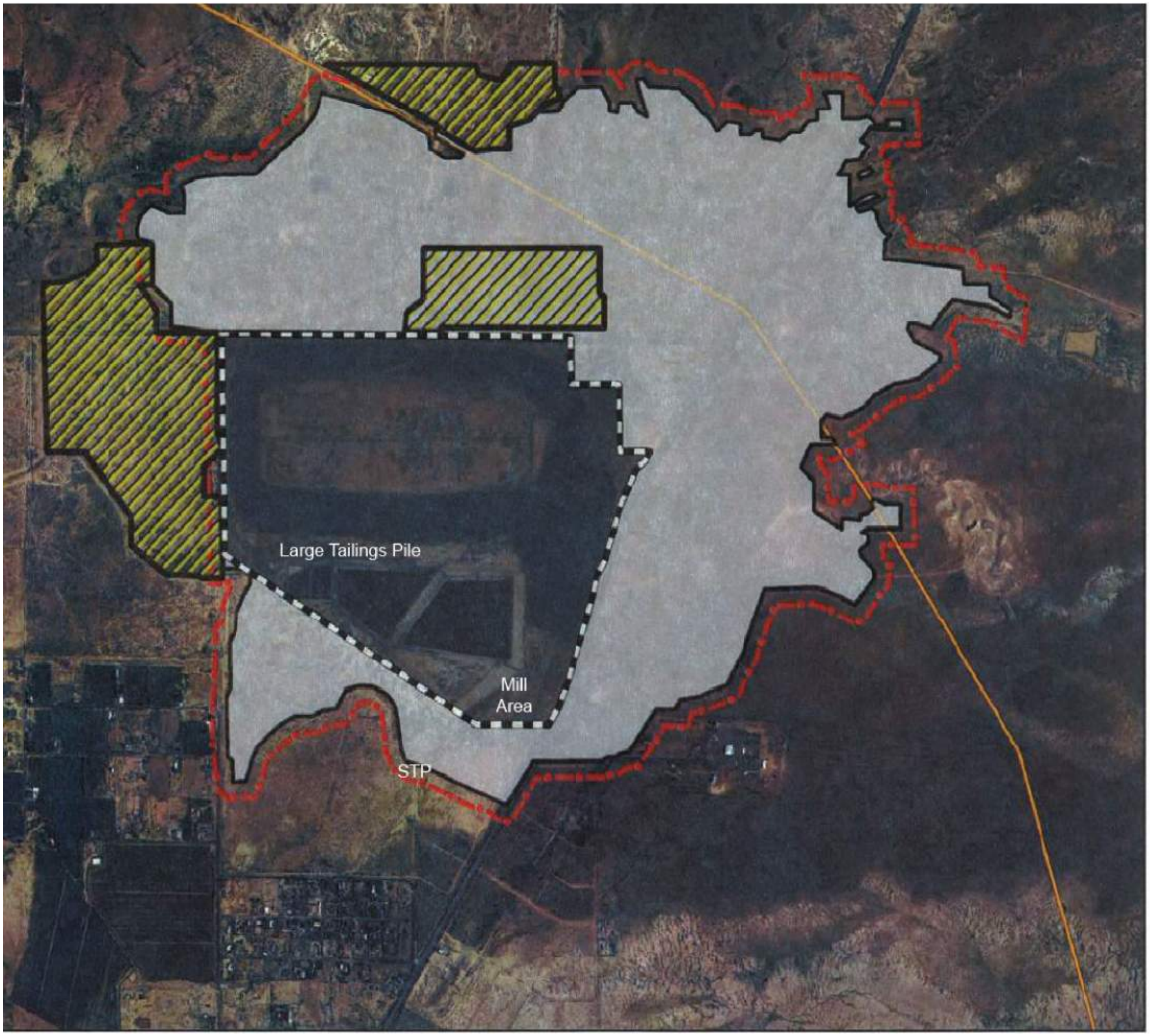
EXTENT OF SAN ANDRES-GLORIETTA AQUIFER

DEVELOPMENT AND SCREENING OF REMEDIAL ALTERNATIVES TECHNICAL MEMORANDUM

FIGURE 1-6



Legend

Inner Zone Remediated Area

Outer Zone Remediated Area

Borrow Pit

Survey Boundary

Transwestern Pipline

STP = Small Tailings Pile

The Inner and Outer Zones Used for Soil Verification

N

0 1,250 2,500 Feet

Prepared by:
Anderson Engineering Co., Inc.
10/20/1995 FIG 3-2.DWG

Source: ERG 1995

Adopted from:
Decommissioning and Reclamation Plan Update 2013 SUA-1471, Homestake Grants Reclamation Project, HMC, 2013

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REMEDIATION OF WINDBLOWN TAILINGS CONTAMINATION AREAS

DEVELOPMENT AND SCREENING OF REMEDIAL ALTERNATIVES TECHNICAL MEMORANDUM

FIGURE 1-7

PATH: D:\PROPOSALS\10171518_BARRICK_RIF_HOMESTAKEMINING\MAP_DOCS\FINAL\TECHMEMORANDUM\FIG1_7_BARRICK_PORTRAIT8X11.MXD - USER: RWOEHL - DATE: 8/1/2019

HOMESTAKE MINING COMPANY